Appendix C

Flow, Passage, Salinity, and Turbidity

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Tables

Acronyms and Abbreviations

BDCP	Bay Delta Conservation Plan
CM	Conservation Measure
CWT	coded wire tag
DCC	Delta Cross Channel
DO	dissolved oxygen
DPM	Delta Passage Model
DRERIP	Delta Regional Ecosystem Restoration Implementation Plan
DWR	California Department of Water Resources
ELT	Early Long-Term
FMWT	fall midwater trawl
km	kilometers
LLT	Late Long-Term
mm	millimeter
OMR	Old and Middle River
PP	Preliminary Proposal
PTM	particle tracking modeling
Reclamation	U.S. Bureau of Reclamation
ROAs	Restoration Opportunity Areas
SAV	submerged aquatic vegetation
SRWQM	Sacramento River Water Quality Model
STN	summer townet
taf	thousand acre-feet

Appendix C
Flow, Passage, Salinity, and Turbidity

[NOTE TO REVIEWER: The following includes only a few components (primarily summaries and conclusions) of the Flow, Passage, Salinity, and Turbidity Appendix. The remainder of the appendix, including detailed descriptions of species exposure, methods used, and results of each specific analysis, will be provided together with the following components on October 14, 2011.]

C.1 Executive Summary

Flows originating upstream, flowing through the Sacramento and San Joaquin River systems and into the Sacramento River–San Joaquin River Delta play a significant role in creating the habitat conditions that fish experience throughout their life cycles. Flow volume, timing, and quality can affect abiotic factors such as salinity, turbidity, dissolved oxygen (DO) concentration, and temperature, as well as influence the total area of wetted habitat accessible to fish. Flows and these related parameters can also influence fish migration patterns through and upstream of the Delta.

Comparison of the Bay Delta Conservation Plan (BDCP) Preliminary Proposal (PP)[1] with existing biological conditions[2] shows that, on average, the total volume of flow in the upstream and Delta areas is generally the same, but some daily, monthly, or water-year-type patterns may shift under the BDCP. Overall, there are minimal upstream changes, but some substantial shifts in how water moves through the Delta under the BDCP. This appendix evaluates the effects on fish that result from changes in flows and flow-related parameters by comparing the BDCP to the existing biological conditions. The BDCP could affect flows and related conditions in four primary ways:

- Conservation Measure (CM) 1 includes the new north Delta intakes, operations of which could affect Sacramento River inflow to the Delta and Delta hydrodynamics.
- CM2 includes Yolo Bypass Fisheries Enhancements, which would improve passage in the Yolo Bypass while somewhat reducing Sacramento River flows between the Fremont Weir and the City of Sacramento.
- CM 4 includes restoration of 65,000 acres of tidal marsh habitat that could result in changes in turbidity and tidal excursion in specific Delta locations and subregions.
- Operations of upstream reservoirs to meet downstream and Delta flow requirements could result in changes in temperatures in key spawning and egg incubation areas, changes in wetted areas that could result in redd dewatering, and changes in accessible rearing habitat.

[1] This condition is based on the set of operations modeling estimates that are available at this time. Additional modeling is underway of an additional operation called Scenario 6, proposed for evaluation by the fishery agencies. When those results are available, a comparison of the results of Scenario 6 with the results presented in this appendix will be conducted. Evaluation of both operational scenarios will inform selection of the Proposed Project upon completion of the Effects Analysis.

[2] Existing biological condltions: this condition is the state of the environment at the time of the analysis and assumes current operations.

This appendix provides a description of the potential mechanisms for changes in flow and the related parameters of temperature, salinity, turbidity, and DO; an overview of the historical operations and management of flows in the CVP and SWP systems; a description of species exposure to potential changes in flows; a description of the methods used to predict the potential effect of changes in flows under the BDCP; results of the application of these methods; and, based on these results, a comprehensive description of the expected flow-related effect on each life stage of each covered fish species. (Population-level effects on each species are presented in Chapter 5.)

The methods used to assess flows and the various flow-related parameters are based on CALSIM and DSM2 outputs, upstream temperature models, particle tracking modeling (PTM), multiple biological models, assumed and measured locations of fish, previous studies in the Delta, Delta Regional Ecosystem Restoration Implementation Plan (DRERIP) analyses, and/or professional judgment. The methods used reflect the best available tools and data regarding fish abundance, movement, and behavior. These methods were applied to a comparison of the PP[3] with two baseline conditions (EBC1 and EBC2) at two time periods in the permit term (Early Long-Term [ELT] and Late Long-Term [LLT]). Table C-1 provides a description of each of these conditions. For some methods, five water-year types were modeled based on the historical CALSIM record to determine the variation in flow-related effects under different flow conditions.

[3] This appendix evaluates flow-related effects under the PP for operation of the BDCP conveyance facilities, as defined by the BDCP Steering Committee (released February 11, 2010, and evaluated in the November 2010 BDCP Working Draft). This evaluation is based on the PP because, at this time, modeling estimates of project operations are available only for this set of operations. Additional modeling is underway of an additional operation called Scenario 6, proposed for evaluation by the fishery agencies. When those results are available, the results of Scenario 6 will be compared to the results presented in this appendix. Evaluation of both operational scenarios will inform selection of the proposed project upon completion of the effects analysis. Scenario 6 is also the operational scenario for several alternatives evaluated in the BDCP environmental impact report/environmental impact statement (EIR/EIS).

Table C-1. Definition of Analytical Conditions

Condition	Description
Existing Biological Condition 1 (EBC1)	This condition assumes current operations based on the 2008 USFWS and 2009 NMFS BOs, excluding the fall X2 actions. Ultimately, this would be similar to how the CVP/SWP has been operated since 2009.
EBC2	This condition assumes current operations based on the 2008 USFWS and 2009 NMFS BOs, including the fall X2 actions called for in the USFWS BO.
EBC1_ELT	This condition assumes that EBC1 continues into the future and includes conditions expected in years 11–15.
EBC1_LLT	This condition assumes that EBC1 continues into the future and includes conditions expected in years 15–50.
EBC2_ELT	This condition assumes that EBC2 continues into the future and includes conditions expected in years 11–15.
EBC2_LLT	This condition assumes that EBC2 continues into the future and includes conditions expected in years 15–50.
Preliminary Proposal (PP)	This condition is based on the set of operations modeling estimates that are available at this time. Additional modeling of an additional operation called Scenario 6, proposed for evaluation by the fishery agencies, is underway. When those results are available, the results of Scenario 6 will be compared to the results presented in this appendix. Evaluation of both operational scenarios will inform selection of the Proposed Project upon completion of the Effects Analysis.
PP_ELT	This condition reflects the preliminary proposal in years 11–15 (prior to the implementation of the new intake facility and the full implementation of the restoration activities).
PP_LLT	This condition assumes full implementation of the BDCP preliminary proposal, and reflects years 15–50.

USFWS = U.S. Fish and Wildlife Service.
NMFS = National Marine Fisheries Service.
BO = biological opinion.
CVP/SWP = Central Valley Project/State Water Project.

The methods used to evaluate flow-related effects include:

- **CALSIM**: Uses historical flow record to estimate reservoir releases and flows for the Sacramento and San Joaquin River systems and Delta under various flow conditions and water project operations.
- **DSM2-HYDRO:** Uses CALSIM output to predict the tidal hydraulic and electrical conductivity (salinity) changes in the Delta channels.
- **DSM2-QUAL:** Uses CALSIM output to predict water temperature, DO, and salinity in the Delta and Suisun Marsh.
- **DSM2-Fingerprinting:** Uses CALSIM output to show sources of flow in Delta channels.
- **DSM2-PTM**: Uses both hypothetical release sites and data from trawls to estimate the movement of larval delta smelt that are assumed to be influenced primarily by flows.
- **MIKE 21**: A two-dimensional hydrodynamic model that predicts water surface elevation, flow, and average velocity at each computational grid cell in the Yolo Bypass.

- **Reclamation Temperature Model:** Uses CALSIM flow and climatic model output to predict temperature in the Trinity, Feather, American, and Stanislaus River basins and upstream reservoirs.
- **Sacramento River Water Quality Model (SRWQM):** Simulates mean daily (using 6-hour meteorology) reservoir and river temperatures at key locations on the Sacramento River based on CALSIM output.
- **Sacramento Ecological Flows Tool:** Links flow management actions to changes in the physical habitats for salmonids using daily flow and temperature output from the SRWQM.
- **Reclamation Egg Mortality Model:** Uses results of water temperature and flow modeling on the upper Sacramento River to estimate Chinook salmon egg mortality.
- **SALMOD:** Estimates juvenile Chinook salmon production in the upper Sacramento River, as a result of effects of flow and temperature on juvenile rearing habitat.
- **Delta Passage Model (DPM):** Uses coded wire tag (CWT) and acoustic tag data to estimate the proportion of Chinook salmon runs that would be occur in various Delta channels and their survival during downstream migration.
- **Effectiveness of Nonphysical Barriers:** Uses results of recent studies at Georgiana Slough and the Old River to determine potential effectiveness of barriers in other Delta locations that would aid in successful migration.
- **DRERIP:** Uses results of scientific studies to establish conceptual models of the stressors and mechanisms that are thought to affect the population dynamics of various resident and migratory fish species, as well as habitat functions.

No single one of these methods could be used for all life stages of all species. As a result, it was necessary to employ these methods in combination to complete the assessment of flow-related effects. For example, the SRWQM could not be applied to San Joaquin River effects, and the DPM can only be applied to Chinook salmon passage through Delta channels.

These methods were applied to each species and life stage as appropriate, and the results of the assessment are presented in Section C.X. The conclusions presented in Section C.4.2 synthesize multiple results because multiple methods were applied to some species and life stages. The conclusions therefore provide a determination of the flow-related effects on each species and life stage.

C.1.1 Overview of Conclusions

Table C-2 summarizes the main conclusions of the effects of BDCP on flow and flow-related parameters. In general, there are very few upstream effects, somewhat adverse effects in the north Delta as a result of decreased flows, improvements in the south Delta as result of increased flows, and mixed results for passage and movement, although adaptive management and monitoring will help improve actual outcomes.

Table C-2. Summary of Conclusions for Flow and Flow-Related Parameters

Upstream Habitat Effects
Except for Sacramento River spring-run and Feather River green sturgeon egg incubation, the BDCP would not result in adverse effects on upstream spawning.
The BDCP would have no effects on spring-run adult holding flows.
Upstream rearing habitat for covered species would not change substantially; however, some adverse effects on late fall–run Sacramento River rearing habitat and on green sturgeon and river lamprey rearing habitat as a result of increases in Feather River temperature, and some benefits to winter-run rearing habitat, are expected.
Passage, Movement, and Migration Effects
Overall, upstream flows during migration and transport periods for anadromous fish are not substantially changed under the BDCP, with some exceptions.
Olfactory cues in the west Delta for upstream anadromous migrating fish will be altered because of shifts in exports from the south Delta to the north Delta under the BDCP.
The BDCP improvements in fish passage facilities at the Fremont Weir and within the Yolo Bypass (CM 2) will reduce delay and stranding of upstream migrating adult anadromous covered fish species.
Chinook salmon smolt survival during outmigration through the Delta includes tradeoffs between positive and negative flow changes in the Yolo Bypass and Sacramento River, with uncertainty to be informed by monitoring and adaptive management.
Reduction in Stockton Deep Water Ship Channel DO levels (CM 14) will improve upstream migration conditions for fall-run Chinook salmon, steelhead, and other species in the San Joaquin River basin.
Modification of the Suisun Marsh Salinity Control Gate operation will improve passage for adult anadromous fish.
Nonphysical fish barriers (CM 16) have the potential to inhibit juvenile fish from entering the interior Delta, but further research is necessary to evaluate effectiveness; unintended passage impedance for adults also requires research.
Reduced Sacramento River flows may reduce longfin smelt and Delta smelt larval transport, with the potential to reduce survival for longfin smelt.
Delta Habitat Effects
Changes in Sacramento River flow may result in an overall decrease in channel margin bench habitat, but restoration will offset this effect.
The general reduction in Old and Middle River (OMR) reverse flows and the corresponding increase in net positive downstream flows through the south Delta channels are expected to improve migration cues, improve migration rates and pathways, and contribute to improved larval and juvenile survival and reduced adult straying, although OMR flows will be greater in certain water-year types.
Increased Yolo Bypass inundation will contribute to substantial biological benefits to splittail spawning and rearing; winter- and fall-run juvenile rearing; and steelhead, late fall–run, green sturgeon, and Pacific lamprey adult migration.

C.2 Overview of Species Exposure to Flow and Flow-Related Parameters

All of the covered fish species would be exposed to BDCP-related changes in flows in the Sacramento River system, the San Joaquin River system, the Delta, or a combination of these areas during their life cycles. Table C-3 indicates which life stages for each species would be exposed to various areas within the Plan Area, which provides the basis for why certain methods and analyses are applicable to the various life stages of each species.

C.3 Summary of Methods Used

Several methods were used to assess the potential effects on fish related to changes in flows from the BDCP. Table C-4 indicates which methods were applied for each area of interest (upstream habitat, Delta habitat, and passage/movement) and to each life stage of each species. Table C-5 provides a description of each method used and its benefits and limitations.

C.4 Conclusions

Table C-6, Table C-7, and Table C-8 summarize the results of the numerous analyses of the effects of the BDCP on flow and flow-related parameters in the Plan Area by species and life stage. Effects of the SWP/CVP are separated by each of five water-year types when possible (wet, above normal, below normal, dry, and critical). For analyses based on limited water years (e.g., analyses using DSM2 modeled flows), summaries were calculated only for all water years. The tables are based on consideration of the percentage change between baseline (EBC1, EBC2, EBC2_ELT, and EBC2_LLT) and the PP (PP_ELT and PP_LLT) for each method applied. *As such, effects shown in each cell reflect multiple independent results for each life stage, and therefore may include multiple colors, and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the rollup in Chapter 5.*

Table C-3. Potential Species Presence and Exposure by Life Stage in the Subregions of the Upstream and Delta Areas, and Potential to be Affected by Changes in Passage

		Upstream Area						Passage and Movement			Delta Area						
Species	Life Stage	Stanislaus River	Mainstem Sacramento River	Feather River	American River	Trinity River	Clear Creek	Yolo Bypass	Stockton Deepwater Ship Channel	Delta and Suisun Marsh Channels	North Delta	South Delta	East Delta	West Delta	Suisun Marsh	Cache Slough	Yolo Bypass
Steelhead	Egg/Embryo																
	Fry																
	Juvenile																
	Adult																
Winter-run Chinook salmon	Egg/Embryo																
	Fry																
	Juvenile																
	Adult																
Spring-run Chinook salmon	Egg/Embryo																
	Fry																
	Juvenile																
	Adult																
Fall-/late fall–run Chinook salmon	Egg/Embryo																
	Fry																
	Juvenile																
	Adult																
Delta smelt	Eggs																
	Larva																
	Juvenile																
	Adult																
Longfin smelt	Eggs																
	Larva																
	Juvenile																
	Adult																
Sacramento splittail	Egg/Embryo																
	Larvae																
	Juvenile																
	Adult																
White sturgeon	Egg/Embryo																
	Larva																
	Juvenile																
	Adult																
Green sturgeon	Egg/Embryo																
	Larva																
	Juvenile																
	Adult																

		Upstream Area						Passage and Movement			Delta Area						
Species	**Life Stage**	**Stanislaus River**	**Mainstem Sacramento River**	**Feather River**	**American River**	**Trinity River**	**Clear Creek**	**Yolo Bypass**	**Stockton Deepwater Ship Channel**	**Delta and Suisun Marsh Channels**	**North Delta**	**South Delta**	**East Delta**	**West Delta**	**Suisun Marsh**	**Cache Slough**	**Yolo Bypass**
Pacific lamprey	Egg/Embryo	■	■	■	■	■	■	□	□	□	□	□	□	□	□	□	□
	Ammocoete	■	■	■	■	■	■	■	□	□	■	■	■	■	□	■	■
	Adult	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
River lamprey	Egg/Embryo	■	■	■	■	■	□	□	□	□	□	□	□	□	□	□	□
	Ammocoete	■	■	■	■	■	□	■	□	□	■	■	■	■	□	■	■
	Adult	■	■	■	■	■	□	■	■	■	■	■	■	■	■	■	■

Notes:

□ = Life Stage not present or likely to be exposed

■ = Life stage present or has potential to be exposed

1

Table C-4. Summary of Methods Used for Each Region and Species Life Stage

Flow Parameter Change or Species Affected	Geographic Region or Life Stage	CALSIM	DSM2-PTM	DSM2-HYDRO	DSM2-QUAL	DSM2-Fingerprinting	MIKE21	Reclamation Temperature Model	Sacramento River Water Quality Model	Delta Passage Model	DRERIP	Sacramento Ecological Flows Tool	Reclamation Egg Mortality Model	SALMOD
Upstream Abiotic Habitat	Sacramento River and San Joaquin River	X						X	X			X	X	X
Fish Movement (Migration, Transport, and Passage)	Yolo Bypass, Lower Sacramento River, Lower San Joaquin River	X	X	X		X				X	X			
Plan Area (Delta) Habitat	North Delta, South Delta, Central Delta	X		X	X		X							
Steelhead	Eggs/Embryo	X						X	X					
	Fry and Rearing Juveniles	X						X	X					
	Juvenile Migrants	X						X	X	X				
	Adults	X				X		X	X					
Winter-run Chinook salmon	Eggs/Embryo	X							X			X	X	
	Fry	X							X			X		X
	Juvenile Migrants	X								X				
	Adults	X				X			X					
Spring-run Chinook salmon	Eggs/Embryo	X						X	X			X	X	
	Fry	X						X	X			X		X
	Juvenile Migrants	X								X				
	Adults	X				X		X	X					
Fall-/late fall–run Chinook salmon	Eggs/Embryo	X						X	X			X	X	
	Fry	X						X	X			X		X
	Juvenile Migrants	X												
	Adults	X				X		X	X					

Flow Parameter Change or Species Affected	**Geographic Region or Life Stage**	**CALSIM**	**DSM2-PTM**	**DSM2-HYDRO**	**DSM2-QUAL**	**DSM2-Fingerprinting**	**MIKE21**	**Reclamation Temperature Model**	**Sacramento River Water Quality Model**	**Delta Passage Model**	**DRERIP**	**Sacramento Ecological Flows Tool**	**Reclamation Egg Mortality Model**	**SALMOD**
Delta smelt	Eggs				X									
	Larva	X	X	X	X									
	Juvenile				X									
	Adult				X									
Longfin smelt	Eggs				X									
	Larva	X	X	X	X									
	Juvenile				X									
	Adult				X									
Sacramento splittail	Eggs/Embryo	X					X							
	Fry	X					X							
	Juveniles	X					X							
	Adults	X					X							
White sturgeon	Egg/embryo	X						X	X					
	Larva	X						X	X					
	Juvenile	X						X	X					
	Adult	X						X	X					
Green sturgeon	Egg/embryo	X						X	X			X		
	Larva	X						X	X					
	Juvenile	X						X	X					
	Adult	X						X	X					

Flow Parameter Change or Species Affected	Geographic Region or Life Stage	CALSIM	DSM2-PTM	DSM2-HYDRO	DSM2-QUAL	DSM2-Fingerprinting	MIKE21	Reclamation Temperature Model	Sacramento River Water Quality Model	Delta Passage Model	DRERIP	Sacramento Ecological Flows Tool	Reclamation Egg Mortality Model	SALMOD
Pacific lamprey	Eggs	X						X	X					
	Ammocoetes	X						X	X					
	Macropthalmia	X												
	Adult	X				X								
River lamprey	Eggs	X						X	X					
	Ammocoetes	X						X	X					
	Macropthalmia	X												
	Adult	X				X								

1 **Table C-5. Description of Methods Used and the Benefits and Limitations of Each Method**

Method	Description of Method	Benefits of Method	Limitations of Method
CALSIM	Provides monthly average flows for entire system based on 82-year record.	Based on historical record and system-wide. Allows comparisons of changes in flows under a range of alternative operations. Used extensively to determine change in water operations and flows.	Monthly time-step limits use for daily or instantaneous effects analysis; does not accurately simulate real-time operational strategies to meet temperature objectives.
DSM2-HYDRO	One-dimensional hydraulic model used to predict flow rate, stage, and water velocity in the Delta and Suisun Marsh.	Numerous output nodes throughout the Plan Area. Provides information in short time-steps that can be used to assess tidal hydrodynamics. Used extensively to determine change in water operations and flows.	One-dimensional model; very data intensive; runs for only 16 years.
DSM2-PTM	Simulates fate and transport of neutrally buoyant particles through space and time in the Delta and Suisun Bay.	Allows assessment of particle fate, transport, and movement rate from numerous starting points to numerous end points. Provides information on movement of planktonic larval fish such as delta and longfin smelt larvae in a tidal environment. Used extensively in Central Valley fishery assessments.	One-dimensional model; no "behavior" can be given to particles; very data intensive and generally only allows tracking for up to 180 days.
DSM2-QUAL	Used to predict water temperature, dissolved oxygen, and salinity in the Delta and Suisun Marsh.	Numerous output nodes throughout the Plan Area. Used extensively in Central Valley fishery assessments.	One-dimensional model; very data intensive; runs for only 16 years.
DSM2-Fingerprinting	Calculates the proportion of water from different sources at specific locations in the Delta.	Allows assessment of water composition at numerous locations throughout the Plan Area. Useful for assessing changes in potential olfactory cues and attraction flows as well as water movement through the Delta.	One-dimensional model; very data intensive; runs for only 16 years.
MIKE21	A two-dimensional hydrodynamic model that predicts water surface elevation, flow, and average velocity in the Yolo Bypass.	Two-dimensional model provides improved definition over one-dimensional models. Can be used to assess changes in physical habitat conditions for fish within the inundated floodplain as a function of specific flows.	The model is static such that changes in flows are not modeled dynamically.

Method	Description of Method	Benefits of Method	Limitations of Method
Reclamation Temperature Model	Uses CALSIM flow and climatic model output to predict monthly water temperature on the Trinity, Feather, American, and Stanislaus River basins and upstream reservoirs.	Large geographic extent makes model widely applicable to BDCP effects analysis. Used extensively in Central Valley fishery assessments.	Monthly time-step limits use for daily or instantaneous effects analysis; does not accurately simulate real-time reservoir operational strategies to meet temperature objectives.
Sacramento River Water Quality Model	Simulates mean daily reservoir and river temperatures at key locations on the Sacramento River based on CALSIM output.	Daily time-step allows for more accurate simulation of real-time operation strategies and can be used to assess temperature effects at a more biologically meaningful time step. Provides input to the Reclamation egg mortality and SALMOD models. Used extensively in Central Valley fishery assessments.	Temporal downscaling routines have limited precision and are not always correct. Cannot reflect real-time management decisions for coldwater pool and temperature management.
Delta Passage Model	Simulates migration and mortality of juvenile Chinook salmon entering the Delta from the Sacramento, Mokelumne, and San Joaquin Rivers through a simplified Delta channel network, and provides quantitative estimates of relative juvenile Chinook salmon survival through the Delta to Chipps Island.	Accounts for movement of migrating juvenile Chinook salmon runs down different Delta channels; based on a growing number of field studies of juvenile salmon migration.	Many of the model assumptions are based on results from large, hatchery-reared late fall-run and fall-run Chinook salmon that may not be representative of smaller, wild-origin fish. Model is applicable only to migrating and not to those rearing in the Delta.
Sacramento Ecological Flows Tool	Links flow management actions to changes in the physical habitats and predicts effects of habitat changes to several fish species.	Incorporates flow and water temperature inputs with multiple model concepts and field and laboratory studies to predict effects on multiple performance measures for fish species; peer-reviewed model.	Limited to upper Sacramento River; limited set of focal species.
SALMOD	Predicts effects of flows on habitat quality and quantity for all races of Chinook salmon in the Sacramento River.	Measures effects of flows on spawning, egg incubation, and juvenile growth as smolt production. Used extensively in Central Valley fishery assessments.	Only assesses effects of flow and water temperature; not reasonably accurate for small spawner numbers (<500 fish).

Method	Description of Method	Benefits of Method	Limitations of Method
Reclamation Egg Mortality Model	Predicts temperature-related proportional losses of Chinook salmon eggs due to operational changes.	Assesses effects at multiple locations within multiple rivers. Used extensively in Central Valley fishery assessments.	Limited to effects on eggs only; monthly time-step limits use for daily or instantaneous effects analysis; third in a sequence of models (CALSIM and Reclamation Water Temperature Model) so limitations of previous models are compounded.
DRERIP	Used to assess importance of stressors, develop methods, and aid in qualitative assessments of BDCP actions in the Plan Area.	Conceptual models have been peer-reviewed and include individual fish species and habitat functions. Provides information on potential stressors and mechanisms for effects analysis.	Outputs are limited to qualitative assessments based on best professional judgment of topical experts.

Table C-6. Summary of Independent Effects of BDCP on Flow in the Upstream Area

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

A. Sacramento River

Species	Life Stage	Metric	Sacramento River (River Mile 194 to Keswick)						Sacramento River (River Mile 143 to 194)						Sacramento River (North Delta to River Mile 143)					
			All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
Steelhead	Egg/Embryo	Spawning habitat[1]							These metrics not analyzed						No spawning habitat present					
		Water temperature																		
		Redd dewatering[1]		Analysis by water year type not conducted																
	Fry/Juvenile	Rearing habitat[1]								Analysis by water year type not conducted					Not a significant rearing reach					
		Water temperature							These metrics not analyzed											
		Stranding[1]																		
Winter-run Chinook salmon	Egg/Embryo	Spawning Habitat[2]							No spawning or rearing below Red Bluff Diversion Dam						No spawning or rearing below Red Bluff Diversion Dam					
		Redd Dewatering[1]		Analysis by water year type not conducted																
	Fry	Habitat[1]		Analysis by water year type not conducted																
	Adult	Water Temperature[3]		Analysis by water year type not conducted																
Spring-run Chinook salmon	Egg/Embryo	Spawning Habitat[2]							No analysis conducted in this reach						No analysis conducted in this reach					
		Redd Dewatering[1]		Analysis by water year type not conducted																
	Fry	Habitat[3,4]		Analysis by water year type not conducted																
		Stranding[1]		Analysis by water year type not conducted																
	Adult	Water Temperature[4]		Analysis by water year type not conducted																
		Holding Flows[3]																		
Fall-run Chinook salmon	Egg/Embryo	Spawning Habitat[2]							No analysis conducted in this reach						No analysis conducted in this reach					
		Redd Dewatering[1]		Analysis by water year type not conducted																
	Fry	Habitat[4]																		
		Stranding[1]		Analysis by water year type not conducted																
Late fall-run Chinook salmon	Egg/Embryo	Spawning habitat	1 10	10	10	10	10	10	Not a significant spawning or rearing reach						No spawning habitat present; not a significant rearing reach					
		Redd scour[6]		Analysis by water year type not conducted																
		Water temperature[7]																		
		Redd dewatering[1]																		
	Fry/Juvenile	Rearing habitat	1 2	2	2	2	2	2												
		Juvenile production[8]		Analysis by water year type not conducted																
		Water temperature																		
		Stranding[1]																		

[1] Based on SacEFT results
[2] Based on SacEFT (all years) and egg mortality model results (by water year type)
[3] Based on water temperature exceedance tables
[4] Based on SacEFT and SALMOD results (all years) and CALSIM flows (by water year type)
[5] Based on percent difference in flow only; assumes that habitat availability is proportional to flow.
[6] Based on percent difference in weighted usable area (WUA) and other SacEFT metrics.
[7] Based on egg mortality model and temperature exceedance analysis.
[8] Score reflects SALMOD results for juvenile production (Red Bluff Diversion Dam) and smolt equivalents.
[10] Based on CALSIM outputs

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

Species	Life Stage	Metric	Sacramento River (River Mile 194 to Keswick)						Sacramento River (River Mile 143 to 194)						Sacramento River (North Delta to River Mile 143)					
			All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
Delta smelt	Eggs		Not found upstream of the Delta																	
	Larva																			
	Juvenile																			
	Adult																			
Longfin smelt	Eggs		Not found upstream of the Delta																	
	Larva																			
	Juvenile																			
	Adult																			
Sacramento splittail	Egg/Embryo		No analysis conducted outside of Plan Area																	
	Fry																			
	Juvenile																			
	Adult																			
White sturgeon	Egg/Embryo	Water Temperature[9]							No analysis conducted in this reach						No analysis conducted in this reach					
		Seasonal Flows[10]	No analysis conducted in this reach																	
	Larva	Water Temperature[11]													No analysis conducted in this reach					
	Juvenile	Water Temperature	No analysis conducted in this reach												No analysis conducted in this reach					
	Adult	Water Temperature[11]													No analysis conducted in this reach					
		Seasonal Flows[12]	No analysis conducted in this reach																	
Green sturgeon	Egg/Embryo	Water Temperature[11]		Analysis by water year type not conducted					No analysis conducted in this reach						No analysis conducted in this reach					
		Seasonal Flows[12]																		
	Larva	Water Temperature[11]													No analysis conducted in this reach					
	Juvenile	Water Temperature[11]													No analysis conducted in this reach					
	Adult	Water Temperature[11]													No analysis conducted in this reach					
Pacific lamprey	Egg/Embryo	Water Temperature[11]		Analysis by water year type not conducted					No analysis conducted in this reach						No analysis conducted in this reach					
		Redd Dewatering[12]																		
	Ammocoete	Water Temperature[11]																		
		Stranding[12]																		

[9] Based on temperature threshold exceedances
[10] Based on CALSIM outputs
[11] Based on SacEFT outputs

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

Species	Life Stage	Metric	Sacramento River (River Mile 194 to Keswick)						Sacramento River (River Mile 143 to 194)						Sacramento River (North Delta to River Mile 143)					
			All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
River lamprey	Egg/Embryo	Water Temperature[11]		Analysis by water year type not conducted					No analysis conducted in this reach						No analysis conducted in this reach					
		Redd Dewatering[12]																		
	Ammocoete	Water Temperature[11]																		
		Stranding[12]																		

B. Clear Creek, Trinity River, and Feather River

Species	Life Stage	Metric	Clear Creek						Trinity River						Feather River					
			All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
Steelhead	Egg/Embryo	Spawning habitat[12]																		
		Water temperature														Analysis by water year type not conducted				
		Redd dewatering[14]																		
	Fry/Juvenile (rearing)	Rearing habitat[14]		Analysis by water year type not conducted																
		Water temperature								Analysis by water year type not conducted						Analysis by water year type not conducted				
Winter-run Chinook salmon	Egg/Embryo		Not found in Clear Creek						Not found in Trinity River						Not found in Feather River					
	Fry Migrants																			
	Juvenile																			
	Adult																			
Spring-run Chinook salmon	Egg/Embryo	Water Temperature[13]														Analysis by water year type not conducted				
		Redd Dewatering[14]																		
	Fry	Water Temperature[15]	No analysis conducted													Analysis by water year type not conducted				
		Stranding[7]																		
	Adult	Water Temperature[8]													16	Analysis by water year type not conducted				
		Holding Flows [16]																		
Fall-run Chinook salmon	Egg/Embryo	Water Temperature[17]																		
		Redd Dewatering[16]							No analysis conducted											
	Fry	Rearing Habitat[18]														Analysis by water year type not conducted				

[12] Based on CALSIM outputs
[13] Based on CALSIM flows (Clear Creek), CALSIM reservoir storage (Trinity River), or temperature threshold exceedances (Feather River)
[14] Based on CALSIM flows
[15] Based on CALSIM flows (Clear Creek and Trinity River) or temperature threshold exceedances (Feather River)
[16] Only one analysis showed an effect that was >5%
[17] Based on CALSIM flows (Clear Creek), temperature threshold exceedances (Feather River, all water years combined), or Reclamation egg mortality model outputs (Trinity and Feather rivers, by water year type)
[18] Based on CALSIM flows (Clear Creek and Trinity River) or SALMOD results (Feather River)

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

Species	Life Stage	Metric	Clear Creek						Trinity River						Feather River					
			All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
Late fall-run Chinook salmon	Egg/Embryo		Not found in Clear Creek						Not found in Trinity River						Not found in Feather River					
	Fry																			
	Juvenile																			
	Adult																			
Delta smelt	Eggs		Not found upstream of the Delta																	
	Larva																			
	Juvenile																			
	Adult																			
Longfin smelt	Eggs		Not found upstream of the Delta																	
	Larva																			
	Juvenile																			
	Adult																			
Sacramento splittail	Egg/Embryo		No analysis conducted outside Plan Area																	
	Fry																			
	Juvenile																			
	Adult																			
White sturgeon	Egg/Embryo	Water Temperature	Not found in Clear Creek						Not found in Trinity River											
		Seasonal Flows																		
	Larva	Water Temperature																		
	Juvenile	Water Temperature																		
	Adult	Water Temperature													No analysis conducted					
Green sturgeon	Egg/Embryo	Water Temperature[19]	Not found in Clear Creek						Not found in Trinity River											
		Seasonal Flows[20]																		
	Larva	Water Temperature[22]																		
	Juvenile	Water Temperature[22]																		
	Adult	Water Temperature[22]																		
Pacific lamprey	Egg/Embryo	Water Temperature[22]	Not found in Clear Creek							Analysis by water year type not conducted						Analysis by water year type not conducted				
		Redd Dewatering[23]																		
	Ammocoete	Water Temperature[22]																		
		Stranding[23]																		
River lamprey	Egg/Embryo	Water Temperature[22]	Not found in Clear Creek							Analysis by water year type not conducted						Analysis by water year type not conducted				
		Redd Dewatering[23]																		
	Ammocoete	Water Temperature[22]																		
		Stranding[23]																		

[19] Based on temperature threshold exceedances

[20] Based on CALSIM outputs

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

B. American, Stanislaus, and San Joaquin Rivers

Species	Life Stage	Metric	American River						Stanislaus River						San Joaquin River					
			All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
Steelhead	Egg/Embryo	Spawning habitat[21]													No spawning habitat present; not a significant rearing reach					
		Water temperature		Analysis by water year type not conducted						Analysis by water year type not conducted										
		Redd dewatering[24]																		
	Fry/Juvenile (rearing)	Rearing habitat[24]								Analysis by water year type not conducted										
		Water temperature		Analysis by water year type not conducted																
Winter-run Chinook salmon	Egg/Embryo		Not found in American River						Not found in Stanislaus River						Not found in San Joaquin River					
	Fry																			
	Juvenile Migrants																			
	Adult																			
Spring-run Chinook salmon	Egg/Embryo	Upstream habitat	Not found in American River						Not found in Stanislaus River											
	Fry	Upstream habitat																		
	Juvenile Migrants														No locations analyzed upstream of Vernalis in San Joaquin River					
	Adult														No locations analyzed upstream of Vernalis in San Joaquin River					
Fall-run Chinook salmon	Egg/Embryo	Instream flows[24]																		
		Water temperature[22]																		
		Redd Dewatering[24]																		
	Fry	Rearing Habitat[24]													No analysis conducted					
Late fall-run Chinook salmon	Egg/Embryo		Not found in American River						Not found in Stanislaus River						Not found in San Joaquin River					
	Fry																			
	Juvenile																			
	Adult																			
Delta smelt	Eggs		Not found upstream of the Delta																	
	Larva																			
	Juvenile																			
	Adult																			
Longfin smelt	Eggs		Not found upstream of the Delta																	
	Larva																			
	Juvenile																			
	Adult																			
Sacramento splittail	Egg/Embryo		No analysis conducted																	
	Fry																			
	Juvenile																			
	Adult																			

[21] Based on CALSIM outputs

[22] Based on Reclamation egg mortality model outputs (American and Stanislaus rivers) or CALSIM flows (San Joaquin River)

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

			American River						Stanislaus River						San Joaquin River					
Species	**Life Stage**	**Metric**	**All**	**Wet**	**Above Normal**	**Below Normal**	**Dry**	**Critical**	**All**	**Wet**	**Above Normal**	**Below Normal**	**Dry**	**Critical**	**All**	**Wet**	**Above Normal**	**Below Normal**	**Dry**	**Critical**
White sturgeon	Egg/Embryo	Water Temperature[23]	Not found in the American River						No analysis conducted						No locations analyzed upstream of Vernalis in San Joaquin River					
		Seasonal Flows[24]							No analysis conducted											
	Larva	Water Temperature[28]																		
		Seasonal Flows[27]							No analysis conducted											
	Juvenile	Water Temperature[28]																		
	Adult	Water Temperature[28]							No analysis conducted											
Green sturgeon	Egg/Embryo		Not found in the American River						Not found in the Stanislaus River						Not found consistently in the San Joaquin River					
	Larva																			
	Juvenile																			
	Adult																			
Pacific lamprey	Egg/Embryo	Water Temperature[28]		Analysis by water year type not conducted						Analysis by water year type not conducted					No locations analyzed upstream of Vernalis in San Joaquin River					
		Redd Dewatering[27]																		
	Ammocoete	Water Temperature[28]																		
		Stranding[27]																		
River lamprey	Egg/Embryo	Water Temperature[28]		Analysis by water year type not conducted						Analysis by water year type not conducted					No locations analyzed upstream of Vernalis in San Joaquin River					
		Redd Dewatering[27]																		
	Ammocoete	Water Temperature[28]																		
		Stranding[27]																		

[23] Based on temperature exceedances

[24] Based on CALSIM outputs

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

Table C-7. Fish Movement and Passage Summary of Independent Effects of BDCP on Covered Species

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

A. Sacramento River

			Sacramento River (River Mile 194 to Keswick)						Sacramento River (North Delta to River Mile 143)					
Species	**Life Stage**	**Metric**	**All**	**Wet**	**Above Normal**	**Below Normal**	**Dry**	**Critical**	**All**	**Wet**	**Above Normal**	**Below Normal**	**Dry**	**Critical**
Steelhead	Egg/Embryo		Non-migratory life stages											
	Fry													
	Juvenile	Migration Flows[1]							No analysis conducted.					
	Adult	Attraction and Migration Flows[1]												
		Kelt Migration Flows[1]												
Winter-run Chinook salmon	Egg/Embryo		Non-migratory life stages.											
	Fry													
	Juvenile	Migration Flows[1]							No analysis conducted.					
	Adult	Attraction and Migration Flows[1]	No analysis conducted.											
Spring-run Chinook salmon	Egg/Embryo		Non-migratory life stages.											
	Fry													
	Juvenile	Migration Flows [1]							No analysis conducted.					
	Adult	Attraction and Migration Flows[1]												
		Holding Flows [1]												
Fall-run Chinook salmon	Egg/Embryo		Non-migratory life stages.											
	Fry													
	Juvenile	Migration Flows[1]							No analysis conducted.					
	Adult	Attraction and Migration Flows [1]												
Late fall-run Chinook salmon	Egg/Embryo		Non-migratory life stages.											
	Fry													
	Juvenile	Migration Flows[1]	No analysis conducted.						No analysis conducted.					
	Adult	Attraction and Migration Flows[1]												
Delta smelt	Eggs	NA	Not found upstream of the Delta.											
	Larva	NA												
	Juvenile	NA												
	Adult	NA												
Longfin smelt	Eggs	NA	Not found upstream of the Delta											
	Larva	NA												
	Juvenile	NA												
	Adult	NA												

[1] Based on CALSIM

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

Species	Life Stage	Metric	Sacramento River (River Mile 194 to Keswick) All	Wet	Above Normal	Below Normal	Dry	Critical	Sacramento River (North Delta to River Mile 143) All	Wet	Above Normal	Below Normal	Dry	Critical
Sacramento splittail	Egg/Embryo	NA	No analysis conducted.											
	Fry	NA												
	Juvenile	NA												
	Adult	NA												
White sturgeon	Egg/Embryo	NA	Non-migratory life stage											
	Larva	Transport Flows[2]	These life stages do not occur above RM 194.											
	Juvenile	Migration Flows[1]												
	Adult	Attraction and Migration Flows[3]												
Green sturgeon	Egg/Embryo		Non-migratory life stage											
	Larva	Transport Flows[1]												
	Juvenile	Migration Flows[1]	No analysis conducted.											
	Adult	Attraction and Migration Flows[1]												
Pacific lamprey	Egg/Embryo		Non-migrating life stage.											
	Ammocoete													
	Macropthalmia	Migration Flows[1]		Analysis by water year type not conducted.					Analysis not conducted.					
	Adult	Attraction and Migration Flows[1]												
River lamprey	Egg/Embryo		Non-migrating life stage.											
	Ammocoete													
	Macropthalmia	Migration Flows[1]		Analysis by water year type not conducted.					Analysis not conducted.					
	Adult	Attraction and Migration Flows[1]												

B. Clear Creek, Trinity River, and Feather River

Species	Life Stage	Metric	Clear Creek All	Wet	Above Normal	Below Normal	Dry	Critical	Trinity River All	Wet	Above Normal	Below Normal	Dry	Critical	Feather River All	Wet	Above Normal	Below Normal	Dry	Critical
Steelhead	Egg/Embryo		Non-migratory life stages																	
	Fry																			
	Juvenile	Migration Flows[1]																		
	Adult	Attraction and Migration Flows[1]																		
		Kelt Migration Flows[1]																		

[2] Differences between EBC and PP scenarios for average number of months per year exceeding 17,700 cfs at Wilkins Slough and 31,000 cfs at Verona (February-May, based on CALSIM).

[3] Differences between EBC and PP scenarios for average number of months per year exceeding 5,300 cfs at Wilkins Slough (November-May, based on CALSIM).

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

Species	Life Stage	Metric	Clear Creek						Trinity River						Feather River					
			All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
Winter-run Chinook salmon	Egg/Embryo		Not found in Clear Creek						Not found in Trinity River						Not found in Feather River					
	Fry Migrants																			
	Juvenile																			
	Adult																			
Spring-run Chinook salmon	Egg/Embryo		Non-migratory life stages																	
	Fry																			
	Juvenile	Migration Flows[1]																		
	Adult	Attraction and Migration Flows[1]																		
		Holding Flows [1]							Analysis not conducted.						Analysis not conducted.					
Fall-run Chinook salmon	Egg/Embryo		Non-migratory life stages																	
	Fry																			
	Juvenile	Migration Flows[1]																		
	Adult	Attraction and Migration Flows[1]																		
Late fall-run Chinook salmon	Egg/Embryo		Not found in Clear Creek						Not found in Trinity River						Not found in Feather River					
	Fry																			
	Juvenile																			
	Adult																			
Delta smelt	Eggs		Not found upstream of the Delta																	
	Larva																			
	Juvenile																			
	Adult																			
Longfin smelt	Eggs		Not found upstream of the Delta.																	
	Larva																			
	Juvenile																			
	Adult																			
Sacramento splittail	Egg/Embryo		Not found in Clear Creek or Trinity River												No analysis conducted.					
	Fry																			
	Juvenile																			
	Adult																			
White sturgeon	Egg/Embryo		Not found in Clear Creek						Not found in Trinity River						Non-migratory life stage					
	Larva	Seasonal Flows													No analysis conducted.					
	Juvenile	Migration Flows[1]																		
	Adult	Attraction and Migration Flows[1]																		

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

Species	Life Stage	Metric	Clear Creek						Trinity River						Feather River					
			All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
Green sturgeon	Egg/Embryo	Water Temperature	Not found in Clear Creek.						Not found in Trinity River.						Non-migratory life stage					
	Larva																			
	Juvenile														No analysis conducted.					
	Adult	Attraction and Migration Flows[1]																		
Pacific lamprey	Egg/Embryo		Not found in Clear Creek.						Non-migratory life stages						Non-migratory life stages					
	Ammocoete																			
	Macropthalmia	Migration Flows[1]							Analysis not conducted.							Analysis by water year type not conducted.				
	Adult	Attraction and Migration Flows[1]																		
River lamprey	Egg/Embryo		Not found in Clear Creek.						Non-migratory life stages						Non-migratory life stages					
	Ammocoete																			
	Macropthalmia	Migration Flows[1]							Analysis not conducted.							Analysis by water year type not conducted.				
	Adult	Attraction and Migration Flows[1]																		

C. American, Stanislaus, and San Joaquin Rivers

Species	Life Stage	Metric	American River						Stanislaus River						San Joaquin River (Vernalis)					
			All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
Steelhead	Egg/Embryo		Non-migratory life stages																	
	Fry																			
	Juvenile	Migration Flows[1]																		
	Adult	Attraction and Migration Flows[1]																		
		Kelt Migration Flows[1]																		
Winter-run Chinook salmon	Egg/Embryo		Not found in American River						Not found in Stanislaus River						Not found in San Joaquin River					
	Fry																			
	Juvenile Migrants																			
	Adult																			
Spring-run Chinook salmon	Egg/Embryo		Not found in American River						Not found in Stanislaus River						Non-migratory life stages					
	Fry																			
	Juvenile Migrants	Migration Flows[1]																		
	Adult																			

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

Species	Life Stage	Metric	American River						Stanislaus River						San Joaquin River (Vernalis)					
			All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
Fall-run Chinook salmon	Egg/Embryo		Non-migratory life stages																	
	Fry																			
	Juvenile	Migration Flows[1]																		
	Adult	Attraction and Migration Flows[1]																		
Late fall–run Chinook salmon	Egg/Embryo		Not found in American River.						Not found in Stanislaus River.						Not found in San Joaquin River.					
	Fry																			
	Juvenile																			
	Adult																			
Delta smelt	Eggs		Not found upstream of the Delta.																	
	Larva																			
	Juvenile																			
	Adult																			
Longfin smelt	Eggs		Not found upstream of the Delta.																	
	Larva																			
	Juvenile																			
	Adult																			
Sacramento splittail	Egg/Embryo		No analysis conducted.																	
	Fry																			
	Juvenile																			
	Adult																			
White sturgeon	Egg/Embryo		Not found in the American River.						No analysis conducted.						No analysis conducted.					
	Larva																			
	Juvenile																			
	Adult																			
Green sturgeon	Egg/Embryo		Not found in the American River.						Not found in the Stanislaus River.						Not found consistently in the San Joaquin River.					
	Larva																			
	Juvenile																			
	Adult																			
Pacific lamprey	Egg/Embryo		Non-migratory life stages						Non-migratory life stages						Non-migratory life stages.					
	Ammocoete																			
	Macropthalmia	Migration Flows[1]								No analysis by water year type.						No analysis by water year type.				
	Adult	Attraction and Migration Flows[1]														No analysis by water year type.				
River lamprey	Egg/Embryo		Non-migratory life stages						Non-migratory life stages							No analysis by water year type.				
	Ammocoete																			
	Macropthalmia	Migration Flows[1]		No analysis by water year type						No analysis by water year type						No analysis by water year type.				
	Adult	Attraction and Migration Flows[1]																		

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

D. Delta Area

Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical
Steelhead	Egg/Embryo		This life stage is not present in the Delta area					
	Fry							
	Juvenile		See Plan Area habitat results summary table for general flow changes					
	Adult	Fremont Weir Passage[1]		Analysis by water year type not conducted				
		Attraction Flows (Sacramento basin populations)[2]						
		Attraction Flows (San Joaquin basin populations)[2]		Analysis by water year type not conducted				
Winter-run Chinook salmon	Egg/Embryo		This life stage is not present in the Delta area or was not analyzed					
	Fry							
	Juvenile	Smolt Through-Delta Survival[3]		Analysis by water year type not conducted				
	Adult	Fremont Weir Passage[1]		Analysis by water year type not conducted				
		Attraction Flows[2]						
Spring-run Chinook salmon	Egg/Embryo		This life stage is not present in the Delta area or was not analyzed					
	Fry							
	Juvenile	Smolt Through-Delta Survival[2]		Analysis by water year type not conducted				
	Adult	Fremont Weir Passage[1]		Analysis by water year type not conducted				
		Attraction Flows (Sacramento basin populations)[2]						
		Attraction Flows (San Joaquin basin populations)[2]	4					

[1] Based on 2009 DRERIP analysis of the Yolo Bypass Conservation Measure (Qualitative score only).
[2] Based on DSM2-QUAL Fingerprinting outputs and CALSIM outputs.
[3] Based on Delta Passage Model.
[4] San Joaquin flow percentage very low under all scenarios.

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical
Fall-run Chinook salmon	Egg/Embryo		This life stage is not present in the Delta area or was not analyzed					
	Fry							
	Juvenile	Smolt Through-Delta Survival (Sacramento basin populations)[2]		Analysis by water year type not conducted				
		Smolt Through-Delta Survival (San Joaquin basin populations)[2]		Analysis by water year type not conducted				
	Adult	Fremont Weir Passage[1]		Analysis by water year type not conducted				
		Attraction Flows (Sacramento basin populations)[2]						
		Attraction Flows (San Joaquin basin populations)[2]	5	Analysis by water year type not conducted				
Late Fall-Run Chinook Salmon	Egg/Embryo		This life stage is not present in the Delta area					
	Fry							
	Juvenile		See Plan Area habitat results summary table for general flow changes					
	Adult	Attraction Flows (Sacramento basin populations)[2]						
Delta smelt	Eggs		Non-migratory life stage					
	Larva	Transport Flows[6]		Analysis by water year type not conducted				
	Juvenile		See Plan Area habitat results summary table for general flow changes					
	Adult							
Longfin smelt	Eggs		Non-migratory life stages					
	Larva	Transport Flows[7]						
	Juvenile		See Plan Area habitat results summary table for general flow changes					

[5] San Joaquin flow percentage very low under all scenarios.

[6] Based on DSM2 Particle Tracking Model outputs.

[7] Based on Kimmerer et al. (2009) X2-abundance regressions.

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

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Species	Life Stage	Metric	All	Wet	Above Normal	Below Normal	Dry	Critical
	Adult							
Sacramento splittail	Egg/Embryo		Non-migratory life stages					
	Larva		See Plan Area habitat results summary table for general flow changes					
	Juvenile							
	Adult							
White sturgeon	Egg/Embryo		This life stage is not present in the Delta area					
	Larva		See Plan Area habitat results summary table for general flow changes					
	Juvenile							
	Adult	Fremont Weir Passage[1]		Analysis by water year type not conducted				
Green sturgeon	Egg/Embryo		This life stage is not present in the Delta area					
	Larva		See Plan Area habitat results summary table for general flow changes					
	Juvenile							
	Adult	Fremont Weir Passage[1]		Analysis by water year type not conducted				
Pacific lamprey	Egg/Embryo		This life stage is not present in the Delta area					
	Ammocoete		See Plan Area habitat results summary table for general flow changes					
	Macropthalmia							
	Adult	Attraction Flows (Sacramento basin populations)[2]		Analysis by water year type not conducted				
		Attraction Flows (San Joaquin basin populations)[2]	4	Analysis by water year type not conducted				
River lamprey	Egg/Embryo		This life stage is not present in the Delta area					
	Ammocoete		See Plan Area habitat results summary table for general flow changes					
	Macropthalmia							
	Adult	Attraction Flows (Sacramento basin populations)[2]		Analysis by water year type not conducted				
		Attraction Flows (San Joaquin basin populations)[2]		Analysis by water year type not conducted				

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

Table C-8. Summary of Independent Effects of BDCP on Flow in the Delta Area

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

A. North Delta, South Delta, and East Delta

		North Delta						South Delta						East Delta					
Species	Life Stage	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
Steelhead	Egg/Embryo	These life stages are not present in the Delta area.																	
	Fry																		
	Juvenile																		
	Adult		Attraction flows are shown in Table C-7.																
Winter-run Chinook salmon	Egg/Embryo	This life stage is not present in the Delta area.																	
	Fry													These life stages are not present in the East Delta area.					
	Juvenile											1							
	Adult		Attraction flows are shown in Table C-7.					This life stage is not present in the South Delta area.											
Spring-run Chinook salmon	Egg/Embryo	This life stage is not present in the Delta area.																	
	Fry													These life stages are not present in the East Delta area.					
	Juvenile										1	1							
	Adult		Attraction flows are shown in Table C-7.					This life stage is not present in the South Delta area.											
Fall-run Chinook salmon	Egg/Embryo	This life stage is not present in the Delta area.																	
	Fry																		
	Juvenile											1							
	Adult		Attraction flows are shown in Table C-7.																
Late fall-run Chinook salmon	Egg/Embryo	These life stages are not present in the Delta area.																	
	Fry																		
	Juvenile													These life stages are not present in the East Delta area.					
	Adult		Attraction flows are shown in Table C-7.					This life stage is not present in the South Delta area.											
Delta smelt	Eggs							This life stage is not present in the South Delta area.						These life stages are not present in the East Delta area.					
	Larva										1	1							
	Juvenile									1	1	1							
	Adult																		
Longfin smelt	Eggs							This life stage is not present in the South Delta area.						These life stages are not present in the East Delta area.					
	Larva																		
	Juvenile											1							
	Adult											1							
Sacramento splittail	Egg/Embryo							These life stages are not present in the South Delta area.											
	Fry																		
	Juvenile										1	1	1						
	Adult																		

[1] These changes reflect increased reverse OMR flows that remain within the requirements of the NMFS and FWS BOs for CVP and SWP operations.

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

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Species	Life Stage	North Delta						South Delta						East Delta					
		All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
White sturgeon	Egg/Embryo	These life stages are not present in the Delta area.																	
	Larva																		
	Juvenile																		
	Adult																		
Green sturgeon	Egg/Embryo	These life stages are not present in the Delta area.																	
	Larva																		
	Juvenile																		
	Adult																		
Pacific lamprey	Egg/Embryo	These life stages are not present in the Delta area.																	
	Ammocoete																		
	Adult		Attraction flows are shown in Table C-7.																
River lamprey	Egg/Embryo	These life stages are not present in the Delta area.																	
	Ammocoete																		
	Adult		Attraction flows are shown in Table C-7.																
All Species	Water temperature		No analysis by water year type.						No analysis by water year type.						No analysis by water year type.				
	Dissolved oxygen		No analysis by water year type.						No analysis by water year type.						No analysis by water year type.				
	Channel margin habitat benches		No analysis by water year type.					No analysis conducted.						No analysis conducted.					

B. West Delta Suisun Marsh, and Cache Slough

Species	Life Stage	West Delta						Suisun Bay						Cache Slough					
		All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
Steelhead	Egg/Embryo	These life stages are not present in the West Delta, Suisun Bay, and Cache Slough areas.																	
	Fry																		
	Juvenile																		
	Adult																		
Winter-run Chinook salmon	Egg/Embryo	This life stage is not present in the Delta, Suisun Bay, and Cache Slough areas.																	
	Fry																		
	Juvenile																		
	Adult																		
Spring-run Chinook salmon	Egg/Embryo	This life stage is not present in the Delta, Suisun Bay, and Cache Slough areas.																	
	Fry																		
	Juvenile																		
	Adult																		

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

Species	Life Stage	West Delta						Suisun Bay						Cache Slough					
		All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
Fall-run Chinook salmon	Egg/Embryo	This life stage is not present in the Delta, Suisun Bay, and Cache Slough areas.																	
	Fry																		
	Juvenile																		
	Adult																		
Late fall-run Chinook salmon	Egg/Embryo	These life stages are not present in the Delta, Suisun Bay, and Cache Slough areas.																	
	Fry																		
	Juvenile																		
	Adult																		
Delta smelt	Eggs																		
	Larva																		
	Juvenile																		
	Adult (Sept-Dec)/with restoration																		
Longfin smelt	Eggs																		
	Larva																		
	Juvenile																		
	Adult																		
Sacramento splittail	Egg/Embryo																		
	Fry																		
	Juvenile																		
	Adult																		
White sturgeon	Egg/Embryo	These life stages are not present in the Delta, Suisun Bay, and Cache Slough areas.																	
	Larva																		
	Juvenile																		
	Adult																		
Green sturgeon	Egg/Embryo	These life stages are not present in the Delta, Suisun Bay, and Cache Slough areas.																	
	Larva																		
	Juvenile																		
	Adult																		
Pacific lamprey	Egg/Embryo	These life stages are not present in the Delta, Suisun Bay, and Cache Slough areas.																	
	Ammocoete																		
	Adult																		
River lamprey	Egg/Embryo	These life stages are not present in the Delta, Suisun Bay, and Cache Slough areas.																	
	Ammocoete																		
	Adult																		

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

Species	Life Stage	West Delta						Suisun Bay						Cache Slough					
		All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical	All	Wet	Above Normal	Below Normal	Dry	Critical
All Species	Water temperature		No analysis by water year type.						No analysis by water year type.						No analysis by water year type.				
	Dissolved oxygen		No analysis by water year type.						No analysis by water year type.						No analysis by water year type.				
	Channel margin habitat benches	No analysis conducted.						No analysis conducted.							No analysis by water year type.				

C. Yolo Bypass

Species	Life Stage	Yolo Bypass					
		All	Wet	Above Normal	Below Normal	Dry	Critical
Steelhead	Egg/Embryo	These life stages are not present in the Yolo Bypass.					
	Fry						
	Juvenile						
	Adult						
Winter-run Chinook salmon	Egg/Embryo	This life stage is not present in the Yolo Bypass.					
	Fry						
	Juvenile						
	Adult						
Spring-run Chinook salmon	Egg/Embryo	This life stage is not present in the Yolo Bypass.					
	Fry						
	Juvenile						
	Adult						
Fall-run Chinook salmon	Egg/Embryo	This life stage is not present in the Yolo Bypass.					
	Fry						
	Juvenile						
	Adult						
Late-fall-run Chinook salmon	Egg/Embryo	These life stages are not present in the Yolo Bypass.					
	Fry						
	Juvenile						
	Adult						
Delta smelt	Eggs	These life stages are not present in the Yolo Bypass.					
	Larva						
	Juvenile						
	Adult						

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

Species	Life Stage	Yolo Bypass					
		All	Wet	Above Normal	Below Normal	Dry	Critical
Longfin smelt	Eggs	These life stages are not present in the Yolo Bypass.					
	Larva						
	Juvenile						
	Adult						
Sacramento splittail	Egg/Embryo						
	larvae						
	Juvenile						
	Adult						
White sturgeon	Egg/Embryo	These life stages are not present in the Yolo Bypass.					
	Larva						
	Juvenile						
	Adult						
Green sturgeon	Egg/Embryo	These life stages are not present in the Yolo Bypass.					
	Larva						
	Juvenile						
	Adult						
Pacific lamprey	Egg/Embryo	These life stages are not present in the Yolo Bypass.					
	Ammocoete						
	Adult						
River lamprey	Egg/Embryo	These life stages are not present in the Yolo Bypass.					
	Ammocoete						
	Adult						
All species	Water temperature		No analysis by water year type.				
	Dissolved oxygen		No analysis by water year type.				
	Channel margin habitat benches	No analysis conducted.					

The effects shown in each cell reflect independent results for each life stage and do not indicate the relative importance of the change to the species. The importance of these changes will be considered and described as part of the roll-up in Chapter 5.

- >75% increase in adverse effects to life stage
- 50–75% increase in adverse effects to life stage
- 25–50% increase in adverse effects to life stage
- 5–25% increase in adverse effects to life stage
- Little change (± ≤ 5%)
- 5–25% increase in beneficial effects to life stage
- 25–50% increase in beneficial effects to life stage
- 50–75% increase in beneficial effects to life stage
- >75% increase in beneficial effects to life stage

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C.4.1 Summary of Changes in Flow

The BDCP would result in very minimal changes in upstream flows or reservoir operations. As such, there are only a few instances in which changes to the environment and related effects on fish may occur. These flow-related temperature effects on spring-run and green sturgeon spawning and egg incubation are described in Section C.4.2. In the Delta, flows in and around the San Joaquin River and south Delta would improve, reflecting the reduced use of the south Delta export facilities. However, the flow patterns in the north Delta could be altered by operations of the new north Delta export facilities and the increased inundation of the Yolo Bypass. These operational changes will reduce some Sacramento River flows, resulting in reduced flows in Sutter, Steamboat, and Georgiana Sloughs and the Delta Cross Channel (DCC). Similarly, the reduced flows in the Sacramento River would subsequently slightly reduce flows in Threemile Slough. These changes in flow patterns in the north Delta can affect the migration and passage of fish through and within the Delta, as described in Section C.4.2. The changes in Delta flows are not expected to result in any substantial changes in turbidity or DO, as described below. However, the changes in Delta operations under the BDCP related primarily to the new north Delta intake could have effects on salinity in some locations, as described below. In most instances, these changes in salinity are compounded by the effects of restoration activities that would occur as part of the BDCP and sea level rise.

C.4.1.1 Upstream Flows

The CALSIM results indicate that there would be little to no change in how reservoirs are operated. The largest changes to reservoir operations result from changes in runoff and inflow caused by climate change unrelated to the BDCP. Coldwater pool management would be excessively challenging for the CVP facilities. Oroville storage generally would be higher under the PP scenarios and would exhibit greater flexibility to adapt to future changes.

In general, the PP would increase carryover storage (end-of-September storage, often the lowest each year) compared to the EBC scenarios. However, CVP and SWP operations are expected to change operations to address the increased outflow needs caused by sea level rise and climate change. These results suggest that the management of storage for the coldwater pool (May storage is an indicator) would be exacerbated in the future, despite the fact that the PP would have increased carryover. The frequency of the end-of-September storage falling below 2,000 thousand acre-feet (taf) would increase by about 10% under both the PP and EBC in the LLT. Considerable adaptation measures would need to be implemented on the upstream operation of the CVP to manage the coldwater pool under the extreme sea level rise and climate change by 2060. Operation of the PP would lessen these challenges, but the effect of climate change and sea level rise would overwhelm these improvements.

These general conclusions are based on the CALSIM data, which are summarized below for each reservoir and river, and the actual operational constraints of the CVP and SWP. Because the CALSIM model uses a monthly timestep, it does not necessarily capture the day-to-day operations that would respond to potential adverse effects, such as temperature changes and minimum flow and storage requirements. However, because the BDCP is not expected to require substantial changes in upstream CVP and SWP operations, the CALSIM results indicating considerable monthly changes are not expected to occur in reality. Rather, California Department of Water Resources (DWR) and U.S. Bureau of Reclamation (Reclamation) reservoir operators would continue to operate the reservoirs and associated flows on a daily basis in a manner that meets flow, storage, and temperature requirements.

C.4.1.2 Delta Flows

The primary changes in Delta operations result from the north Delta intakes and the increased flows into the Yolo Bypass at the Fremont Weir. These changes generally divert water from the Sacramento River into either the new intake or the Yolo Bypass, reducing flows in Sutter, Steamboat, Threemile, and Georgiana Sloughs; in the DCC; and at Rio Vista. Reductions in south Delta pumping that are possible with the north Delta intakes increase OMR flows and San Joaquin River flows at Antioch by the amount of the reduced pumping. While climate change may affect flows in the San Joaquin, Mokelumne, and Cosumnes Rivers, no effects from the BDCP are expected in the Delta channels connected to these river inflows. A summary of changes at each Delta location is provided below. However, these changes reflect the general trends and not necessarily the outer bounds of potential changes that could occur across water-year types and months within those water years. The effects analysis used detailed modeling results to determine the biological responses to specific daily, monthly, and water-year-type changes. These are reported in the results section above (to come).

C.4.1.2.1 Sacramento River Flows at Freeport

The Sacramento River flow at Freeport is the major Delta inflow and represents the water available for diversion at the proposed north Delta intakes. The average annual inflow at Freeport was reduced by about 650 taf, primarily as a result of the increased Fremont Weir spills into the Yolo Bypass that would occur under the BDCP. Similarly, PP_ELT and PP_LLT monthly median flows at Freeport were similar to EBC1, but were shifted in some months as a result of the increased spills at the Fremont Weir and other changes in upstream reservoir releases, as discussed above.

The Freeport median flows were similar in October, November, and December for the EBC1 and BDCP cases. The Freeport median flows in January, February, and March for the BDCP cases were about 3,000 cfs less than EBC1 flows, reflecting the increased spills at the Fremont Weir into the Yolo Bypass. The April and May median flows at Freeport were similar for the PP cases and EBC1 conditions. The June median flows were increased for the BDCP cases. The Freeport median flows for the PP cases in July, August, and September were reduced by about 3,000 cfs compared to EBC1 flows because of changes in upstream reservoir releases. The BDCP north Delta intakes allowed higher exports in April, May, and June, and subsequently allowed reduced reservoir releases and reduced exports. The PP cases had inflows and exports that were distributed more evenly during the highest agricultural demand period of April through September.

C.4.1.2.2 San Joaquin River Flows at Vernalis

The only changes in the San Joaquin River flows are caused by the assumed climate change effects on reduced San Joaquin River (above Friant Dam) inflows and reduced tributary inflows. No changes from BDCP operations were simulated.

C.4.1.2.3 Yolo Bypass Flows to the Delta

The Yolo Bypass flow is nearly identical to the Fremont Weir spills, with the addition of the Cache Creek and Putah Creek flows entering the bypass in months with relatively high runoff. Although the BDCP ELT and LLT cases allow some additional flows into the Yolo Bypass at the Fremont Weir, the monthly sequence of Yolo Bypass flows was very similar. A few more months have flows of 3,000–5,000 cfs (notch capacity), and the high-flow months have slightly more flow (5,000 cfs).

C.4.1.2.4 Mokelumne River and Cosumnes River Flows to the Delta

The monthly inflows from the Mokelumne River near Thornton, just below the Cosumnes River, are very low during the summer months. These flows were nearly identical for all CALSIM cases. Most Cosumnes River runoff enters the Delta, and the Mokelumne River is highly regulated by Pardee and Camanche Reservoirs. The minimum flows below Woodbridge Dam are specified based on runoff, and reservoir spills are rare. There were no effects from the BDCP on these river flows.

C.4.1.2.5 San Joaquin River Diversions to Old River

The BDCP would not result in changes in the San Joaquin River flows at the Old River, but some changes are expected as a result of climate change. The median head of the Old River flow for December through May was about half of the San Joaquin River flow at Vernalis. The median flows in June through September were about 40% of the San Joaquin River flow at Vernalis because of the effects of the south Delta rock barriers. The annual average head of the Old River diversion flow was nearly the same for all six CALSIM cases and was equal to about half of the San Joaquin River flow.

C.4.1.2.6 Old and Middle River Flows

The CALSIM modeling assumed that some OMR reverse flow restrictions would apply for each of the applicable months (December through June). The restrictions were assumed to vary somewhat with runoff conditions. The assumed restrictions were held constant for each of the EBC1 cases, the three EBC2 cases, and the two BDCP cases. Because negative OMR flow is toward the south Delta pumps, the greatest negative values indicate higher pumping. The minimum values indicate the maximum pumping from the central Delta. For example, the October and November minimum flows for EBC1 were -10,000 cfs. The October and November median flows were -8,000 cfs. However, there are no OMR flow restrictions in October and November. The EBC1 December minimum flow was -9,600 cfs, but the median flow was -5,871 cfs (the assumed OMR limit in 30% of the years). This suggests that the OMR limits were reducing the December exports to this level in several of the years. The January through March and June minimum flows were -5,000 cfs because the assumed OMR limits were restricting pumping to this level in many of the years in these months. The minimum flows in April and May were higher than the limit of -5,000 cfs because the NMFS exports/San Joaquin River ratio that applies in April and May was reducing the exports more than the OMR limits. EBC1 flows in July through September were -11,000 to -10,000 cfs, and median flows were -10,000 to -9,000 cfs.

The BDCP ELT and LLT cases shifted pumping from the south Delta to the north Delta intakes, and thereby increased the OMR flows (reduced negative OMR flows). The median OMR flows for the BDCP ELT and LLT cases were about 2,000 cfs higher in October and November, about the same in December, 2,000 cfs higher in January, 5,000 cfs higher in February, and 3,500 cfs higher in March, 1,500 cfs higher in June, 6,000 cfs higher in July, 6,500 cfs in August, and 4,500 cfs higher in September.

C.4.1.2.7 Sutter Slough and Steamboat Slough Flows

The Sutter and Steamboat Slough diversions are about 40% of the Sacramento River flow. The monthly median diversion flows into Sutter and Steamboat Sloughs were similar for the EBC1 case and the three EBC2 cases because the Sacramento River flows were similar. The median diversions into Sutter and Steamboat Sloughs were lower for the PP_ELT and PP_LLT cases because the north Delta intakes reduce the Sacramento River flow at Sutter and Steamboat Sloughs. The median diversions in October, April, May, and June were about the same for the baseline and the BDCP cases. The median diversions were reduced by 1,000 cfs in November, July, and September; 2,000 cfs in January and August; and 4,000 cfs in February and March. The reductions in the Sutter and Steamboat Slough diversions were about 40% of the simulated north Delta intake diversions. The annual average diversions into Sutter and Steamboat Sloughs were about 6,500 taf (42% of the Sacramento River flow at Freeport) for the EBC1 case and three EBC2 cases, and were reduced to about 5,500 taf (36% of the Sacramento River flow at Freeport) for the two BDCP cases.

C.4.1.2.8 Delta Cross Channel and Georgiana Slough Flows

Similar to Steamboat and Sutter Sloughs, the PP_ELT and PP_LLT cases had reduced monthly median diversion flows because the north Delta intakes reduced the Sacramento River flow. The annual average diversions into the DCC and Georgiana Slough were about 3,750 taf (24% of the Sacramento River flow at Freeport) for the EBC1 case and three EBC2 cases, and were reduced to about 3,150 taf (21% of the Sacramento River flow at Freeport) for the two BDCP cases.

C.4.1.2.9 Sacramento River Flows at Rio Vista

The minimum flows in September through December for Rio Vista (3,000–4,500 cfs, depending on water-year type) were generally satisfied. The EBC1 monthly median flows were about 5,500 cfs in October, 7,500 cfs in November, 12,500 cfs in December, 22,000 cfs in January, 29,000 cfs in February, 23,000 cfs in March, 13,000 cfs in April, 10,000 cfs in May, 6,500 cfs in June, 10,500 cfs in July, 8,500 cfs in August, and 6,500 cfs in September. The median flows at Rio Vista for the three EBC2 cases were similar because the Yolo Bypass and Sacramento River inflows were generally the same. The median monthly Rio Vista flows were reduced in the months when the north Delta intake diversions were simulated for the PP_ELT and PP_LLT cases. The reduced Rio Vista flows were generally about the same as the north Delta intake diversions. The annual average Sacramento River flows at Rio Vista were about 14,000 taf for the EBC1 case and three EBC2 cases, and were reduced to about 12,000 taf for the PP_ELT and PP_LLT cases.

C.4.1.2.10 Threemile Slough Flows

The Threemile Slough flows are about 3% of the Rio Vista flows and were reduced slightly for the BDCP cases because the Rio Vista flows were reduced by the north Delta intake diversions. The annual average Threemile Slough flows were about 1,000 taf for the EBC1 case and the three EBC2 cases, and were reduced to about 750 taf for the two BDCP cases.

C.4.1.2.11 San Joaquin River Flows at Antioch

San Joaquin River flows at Antioch were increased in the PP_ELT and PP_LLT cases because the reduction in south Delta exports will increase OMR and San Joaquin River flows by the same amount. For the BDCP cases, the monthly median flows were about 0 cfs in October and November, and were reversed to -2,000 cfs only in December. The San Joaquin River flows were about 1,500 cfs in January, 8,500 cfs in February, 6,500 cfs in March, 3,000 cfs in April, 2,500 cfs in May and June, 1,000 cfs in July, 500 cfs in August, and 150 cfs in September. The summer periods of reverse San Joaquin River flow were generally eliminated by the BDCP north Delta intake diversions.

C.4.1.2.12 Delta Outflow

The CALSIM-simulated Delta outflow is the sum of all the upstream and Delta operations, and it is the major link with salinity in the Delta and with the X2 position. Delta outflow requirements often limit the Delta exports, so the simulated Delta outflow for many months is equal to the minimum Delta outflow requirement for each month. The EBC1 case did not include the BO Fall X2 requirements, so the required Delta outflow was controlled by the D-1641 objectives. The annual average outflow required for EBC1 (D-1641) was 4,250 taf. The three EBC2 cases included the BO Fall X2 requirements, and the average annual required outflow was about 5,000 taf for EBC2, about 5,250 taf for EBC2_ELT, and about 5,750 taf for EBC2_LLT. The BO Fall X2 requirements raised the annual average required outflow for EBC1 by about 750 taf. The EBC2_ELT and EBC2_LLT cases had even higher required outflows caused by changes in the outflow required to meet X2 because of sea level rise and habitat restoration effects on salinity intrusion.

The monthly median outflows for the EBC1 case were 4,000 cfs in October, 5,000 cfs in November, 8,000 cfs in December, 22,000 cfs in January, 36,500 cfs in February, 27,000 cfs in March, 19,000 cfs in April, 16,000 cfs in May, 7,000 cfs in June, 8,000 cfs in July, 4,000 cfs in August, and 3,600 cfs in September. About half of the months had excess Delta outflow compared to the outflow requirements, but the outflow in most of these months was likely controlled by the maximum allowed E/I ratio.

The monthly median outflows for the PP_ELT and PP_LLT cases were similar (within 1,000 cfs) to the EBC1 median outflows in October through February, 2,000 cfs less in March, 6,000 cfs less in April, 4,000 cfs less in May, and similar in June through September. The annual average Delta outflow for the EBC1 case was 15,500 taf. The annual average outflows were 14,875 taf for the PP_ELT case and 15,200 taf for the PP_LLT case.

C.4.1.3 Salinity

Salinity is included in this appendix to assess the potential for changes to habitat as a result of changes in flows that may cause changes in salinity. (Salinity as a drinking water quality parameter is addressed in the BDCP EIR/EIS.) The BDCP allows more salt into the western Delta because of increased tidal mixing associated with the addition of tidal marsh areas and reduced Delta outflow. Substantial increases in salinity at Emmaton and moderate increases at Jersey Point and Rock Slough caused by the BDCP are generally attributable to the reduction in Sacramento River flows in these areas. However, slight improvements in average annual salinity at Threemile Slough are expected as a result of major salinity decreases in July and August. As the BDCP is implemented and more tidal marsh is restored, salinity effects at these compliance locations intensify. At Emmaton under PP_LLT, the largest increases in salinity occur from May to September, while there are minimal changes in salinity from October through April. Jersey Point and Rock Slough are also expected to have additional increases in salinity in the LLT as a result of restoration activities. The annual average salinity at Threemile Slough is further reduced in the LLT because of substantial salinity reductions in October and November resulting from higher Sacramento River flow.

Salinity can be controlled somewhat by Delta outflow. Higher Delta outflow moves the salinity gradient west and lowers the X2 (decreases the distance from the Golden Gate). Under the PP scenarios, X2 moves upstream (lower outflow) in some months, with the reduced inflows or higher exports that were allowed with the north Delta intake. However, the PP scenarios will meet the required D-1641 X2 locations from February through June and the minimum Delta outflows, as described above.

The EBC1 X2 positions calculated by CALSIM ranged from 67 to 95 kilometers (km) in October, 52 to 94 km in November, 47 to 92 km in December, and 47 to 90 km in January. The EBC1 baseline X2 during the months with X2 requirements ranged from 47 to 87 km in February, 47 to 83 km in March, 47 to 83 km in April, 48 to 87 km in May, and 49 to 75 km in June. The CALSIM-simulated X2 ranged from 56 to 91 km in July, 66 to 91 km in August, and 63 to 92 km in September. The three EBC2 cases, which included BO Fall X2 requirements in September through November of about half of the years (Wet and Above Normal), had corresponding reduced X2 values in the 50–90% cumulative values. The changes in the monthly X2 ranges or in the monthly median values were relatively small because the monthly range in outflows remained similar for each of the EBC1 and EBC2 baseline cases. The BDCP cases allowed some of the X2 positions to move upstream (lower outflow), with the higher exports that were allowed in some months with the north Delta intake. The required D-1641 X2 locations from February through June and the minimum Delta outflows were satisfied by the BDCP cases.

Although differences were detected in the location of X2 during fall months among the EBC and PP operations developed through this effects analysis, the results of the analyses of potential mechanisms associated with X2 location and basic population response (e.g., juvenile production per adult), indicate that the differences in X2 location in and of itself are not significant factors affecting Delta smelt abundance or population dynamics among the alternatives.

Feyrer et al. (2007, 2011) used results of the analysis of presence and absence of Delta smelt and associated salinity and turbidity as a basis for hypothesizing that the location of the low-salinity zone within the Delta and Suisun Bay was a key factor affecting Delta smelt in the fall. Data on the surface area of waters that met the salinity and turbidity criteria for suitable habitat as defined by Feyrer et al. (2007, 2011) were plotted as a function of the location of the 2-psu bottom salinity isohaline (X2) location. The relationship between X2 locations and the index of habitat (hectares) developed by Feyrer et al. (2011) predicted that the surface area that meets the salinity and turbidity preference considered by Feyrer et al. (2007) to be suitable for Delta smelt decreases in the fall.

There have been a number of technical criticisms regarding the approach adopted by Feyrer et al. (2007, 2011), causing uncertainty about the utility of the habitat index. Technical concerns regarding the approach include linking statistical models without accounting for uncertainty; use of only two abiotic habitat factors; weakness of correlation; portion of population excluded from analysis; and apparent induced correlation. The underlying biological mechanism that would explain the potential importance of the Feyrer et al. habitat index is similarly unclear.

The actual mechanisms underlying the hypothesized relationship between X2 locations in the fall and the health and condition of prespawning adult Delta smelt are unknown. Several potential mechanisms have been identified and tested using data primarily from the DFG fall midwater trawl (FMWT) surveys extending back to 1967. Data from the FMWT surveys were used to examine the potential relationship between fall X2 location and the geographic distribution of Delta smelt. Results of these analyses showed that the centroid of the Delta smelt geographic distribution moves upstream and downstream in relationship to fall X2 location (Sommer et al. 2011), but Delta smelt are distributed broadly over relatively large area (frequently a 40-km range or more) extending both upstream and downstream of the X2 location (Hanson 2011).

Additional analyses examined the relationship between X2 locations and survival of prespawning Delta smelt in the fall using both DFG monthly indices of Delta smelt abundance each year and refined estimates of Delta smelt abundance derived from FMWT surveys by Newman (2008). As a result of high variability in the estimated fall survival rates derived from these analyses, no conclusions were drawn regarding the potential relationship between fall X2 location and Delta smelt survival in the fall.

Analyses were conducted to examine the potential relationship between fall X2 locations and the subsequent reproductive success of Delta smelt the following spring. It was hypothesized that if habitat conditions, growth, egg production, and adult smelt size in the fall were improved as a result of the location of fall X2, then it would be expected that there would be an increase in the number of larval and juvenile Delta smelt per adult in the spring. In contrast, if habitat conditions in the fall were poor for prespawning adult smelt as a result of the upstream location of X2, then it would be expected that fewer larval and juvenile Delta smelt would be produced per adult in the spring. Data from the DFG FMWT survey were used as an indicator of prespawning adult smelt abundance in the fall, and data from the CDFG 20-millimeter (mm) larval Delta smelt surveys and summer townet (STN) survey were used as indices of juvenile Delta smelt abundance the following spring. Results of analyses detected no significant relationship between the location of X2 in the fall and the production of young Delta smelt the following spring (Hanson 2011).

Results of analyses using the DFG zooplankton surveys were used to assess the relationship between densities of copepods (*Eurytemora affinis*, *Pseudodiaptomus forbesi*, and *Pseudodiaptomus mainus*) that are the primary food resources of adult Delta smelt and X2 location in the fall. Results of these analyses did not detect a significant relationship between copepod densities and X2 location, but did detect significant relationships between copepod densities during the fall months and Delta smelt abundance (catch) at associated sampling sites, suggesting that Delta smelt abundance is greater in areas of the estuary where their copepod food resources are greatest (Hanson 2011). Based on these results, it was speculated that one mechanism underlying the fall X2 hypothesis is the potential that zooplankton densities are greater in the broad shallow areas of Suisun Bay in the fall when compared to areas upstream of the lower Sacramento River confluence. Data from the DFG zooplankton surveys were analyzed to test the hypothesis that copepod densities are greater in the fall in Suisun Bay when compared to the lower Sacramento River. In fact copepod densities have been higher in the lower reaches of the Sacramento River over the past decade when compared to copepod densities observed further downstream in Suisun Bay.

A similar hypothesis suggests that turbidity levels are greater in Suisun Bay when compared to the lower Sacramento River, and that high turbidity would benefit Delta smelt when X2 is located downstream through reduced vulnerability to predation and greater ability to detect copepod food supplies. Data from the DFG FMWT surveys were used to analyze whether there were differences in fall turbidity levels. During each FMWT sample, DFG records the visibility (secchi depth) of the water, which serves as an indicator of turbidity. Analysis of the DFG secchi depth data did not detect a significant difference in turbidity in the fall between the lower Sacramento River and Suisun Bay.

Based on these multiple lines of analysis, it was concluded that the relationship between the surface areas of abiotic habitat based on salinity and turbidity identified by Feyrer et al. (2007, 2011) and USFWS (2008) varies as a function of X2 location in the fall, but that no significant mechanisms have been identified regarding the biological linkage between fall X2 location and the mechanisms underlying the population dynamics of Delta smelt.

Lifecycle population modeling has also been conducted in recent years to assess the potential relationships between the location of X2 in the fall, or abiotic habitat surface area as suggested by Feyrer et al. (2011) and USFWS (2008) and abundance or survival of Delta smelt. Feyrer et al. (2007) used a linear additive model to examine the potential relationship between three abiotic variables (salinity, turbidity, and temperature) or X2 locations and adult smelt abundance in the fall and subsequent production of juvenile Delta smelt the next spring. Results of the modeling did not detect a significant population (stock-recruitment) relationship when the full data set extending back to 1967 was used in the analysis, but did detect a significant relationship when the data were limited to a period starting in 1987 (1987–2004). Results of the delta smelt population modeling on the potential relationship between fall X2 location and subsequent abundance of juvenile delta smelt developed by Feyrer et al. were subsequently withdrawn and have not been independently peer reviewed or published in the scientific literature.

Additional more-sophisticated lifecycle population models have been developed recently for Delta smelt by MacNally et al. (2010), Thompson et al. (2010), and Maunder and Deriso (2011). Quantitative lifecycle population models are a tool that can be used to determine which habitat factors that surround the species have a statistically significant effect on the species population dynamics and abundance over time. Lifecycle models can then be used to determine the degree to which changes in habitat variables explain observed changes in population growth rates for the species (e.g., the rate of increase or decrease in population abundance). Appendix E, Fish Population Analysis, specifically analyzes the results of the available lifecycle models. Additionally, Appendix F, Habitat Restoration, will further explore the various components of Delta smelt habitat and how the BDCP may affect it.

C.4.1.4 Turbidity

Firm conclusions regarding changes in turbidity in the BDCP Plan Area are difficult to make. Uncertainty in sediment supply in the future is high, and factors such as the timing of establishing the Restoration Opportunity Areas (ROAs) and the potential use of options such as fill-in materials or wind breaks in the ROAs to reduce wind-driven resuspension preclude all but the most general analysis. The present analysis focused on whether the different subregions would become erosional (increasing turbidity) or depositional (decreasing turbidity) and whether seasonal wind resuspension within ROAs is likely to be greater (thereby increasing turbidity). Factors such as submerged aquatic vegetation (SAV), benthic filter feeders, organic materials, and the potential substantial effects on the critical shear stress of erosion from changes in benthic algae and macrofauna have not been considered in the present analysis.

The Delta will remain regionally depositional in the LLT time frame, in both EBC and PP scenarios, although the location of the depositional regions will differ. The effects of sea level rise will depend on the balance between sediment supply from the watersheds and the rate of sea level rise, so it is unclear whether sediment supply will be sufficient to maintain the current extent of tidal marsh. The initial effect of the ROAs in the PP is to decrease sediment supply downstream, but the longer-term effects are uncertain as the ROAs reach a dynamic equilibrium.

Under the PP, the north Delta subregion will receive less sediment because of increased flows through the Yolo Bypass, but this may not be a large enough factor to differentiate these effects from the overall effects due to sea level rise and climate change alone in the LLT under existing conditions. The Cache/Yolo-region ROAs will become depositional with sediment that would otherwise be carried down the Sacramento River. While the ROAs have the potential to increase water clarity in existing open water areas such as Liberty Island at least initially, wind resuspension of unconsolidated sediment during the summer is likely to decrease water clarity in the region seasonally. The west Delta ROA will accrete sediment, resulting in a local increase in water clarity in combination with decreased supply due to sediment deposition in the Cache/Yolo region. However, decreased sediment supply could result in erosion and a decrease in water clarity, leaving a mixed picture for this region. The east Delta subregion is likely to experience increased water clarity due to the ROAs, both because of decreased flow through Georgiana Slough and because of deposition in the east Delta ROAs of the small amount of sediment originating from the Mokelumne and Cosumnes Rivers. The effect of seasonal winds will be minor because the ROAs are not large in the east Delta. The south Delta ROA consists of large open water areas that (barring establishment of SAV such as *Egeria densa*) will likely experience decreased water clarity due to wind resuspension in the summer. However, deposition in the ROAs could also increase water clarity, resulting in an overall mixed picture.

The effect of the Suisun Bay region ROAs, both locally and due to effects from upstream ROAs, is complicated. Suisun Bay is currently erosional and the opening of ROAs upstream is likely to increase this erosion. If Suisun Bay continues to deepen and intertidal regions are lost, wind waves will become less effective at suspending sediment, so erosion rates may slow even in the presence of reduced sediment supply. The new ROAs may exert a local decrease in water clarity from seasonal resuspension due to wind. However, predicting the balance between the depositional environment in the ROAs and increased regional erosion is very complicated, so the overall result for water clarity is uncertain. The ROAs in Suisun Marsh will likely be depositional because of local sediment supply, resulting in local increases in water clarity. The effects of wind resuspension in decreasing water clarity will likely be limited to the larger ROAs in this region, depending on wind direction.

The effects of turbidity on fish are not directly linked to survival and are only one component of habitat that may be required for species success. As such, similar to the salinity changes described above, the effects of turbidity on fish and fish habitat will be further explored in Appendices E (Fish Population Analyses) and F (Habitat Restoration) to better integrate the multiple factors comprising fish habitat and the potential effects of BDCP on it.

C.4.1.5 Temperature and Dissolved Oxygen

Some temperature changes are expected to occur in some years in some upstream rivers. However, these changes rarely translate to adverse effects on species, as described below. In-Delta water temperature and DO concentrations are not expected to change in response to the BDCP. Water temperatures and DO in the Delta are primarily affected by atmospheric conditions (air temperature, winds, solar radiation, and climate change). Water temperatures are typically in thermal equilibrium with the atmospheric conditions and therefore are not influenced strongly by changes in river flows affected by proposed project operations. Similarly, DO concentrations in the river channels and bays are typically in equilibrium with atmospheric conditions, and proposed project operations are not anticipated to result in biologically significant changes within the Delta. As a result of these factors, it was concluded that proposed project operations would not result in adverse changes in either water temperatures or DO concentrations within the Delta that would affect the target species. Changes in long-term seasonal water temperatures are anticipated to occur within the Delta, however, in response to future climate changes that are independent of proposed project operations, but that are also expected to result in changes in habitat conditions that could potentially adversely affect the population dynamics of the covered species in the future (LLT climate changes).

C.4.2 Flow-Related Biological Effects

The following information is summarized in Table C-6, Table C-7, and Table C-8 above, and describes in detail the conclusions for each species for flow-related parameters in upstream and Delta areas, and for passage, migration, and movement.

C.4.2.1 Upstream Spawning and Egg Incubation

Except for Sacramento River spring-run and Feather River green sturgeon egg incubation, the BDCP would not result in adverse effects on upstream spawning.

Overall, there would be minimal changes to upstream flows and as such, very few effects on spawning and egg incubation. Most of the differences and associated effects on spawning and egg incubation habitat observed among the modeled scenarios were attributable to near-term and long-term climate change effects. In many instances, increased steelhead, winter-run, Pacific lamprey, and river lamprey egg mortality under future conditions is primarily a result of natural seasonal and interannual variation in river flows, coldwater storage, and temperature effects on incubating eggs that were largely independent of BDCP operations. Decreased temperatures during egg incubation periods for spring-run on the Sacramento River and green sturgeon on the Feather River would result in adverse effects on these species.

Steelhead. No adverse effects were detected on steelhead spawning and egg incubation habitat conditions based on CALSIM, SacEFT, and water temperature modeling results. The predicted magnitude and frequency of instream flows, reservoir storage, and water temperatures potentially affecting the quantity and quality of spawning and incubation habitat under proposed project and future baseline conditions were comparable. Based on the results, BDCP operations would likely have small annual effects on flows and water temperatures during the steelhead spawning and incubation period, but would not affect long-term habitat conditions relative to future baseline conditions.

Winter-run Chinook salmon. No major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., reservoir storage, instream flows, and water temperatures during egg incubation) for Sacramento River winter-run Chinook salmon based on results from the Reclamation egg mortality model, SacEFT, SALMOD, and other tools. Positive and negative changes in instream flows that affect habitat quality and quantity, such as reduced summer and fall flows relative to existing conditions, were detected in the Sacramento River. Differences in flow in the Sacramento River in September of wetter years between existing and BDCP operations reflect, in large part, differences in fall operations for downstream low-salinity habitat that was included as an operating criterion under the EBC2 conditions but was not included in BDCP operations.

Spring-run Chinook salmon. No major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., reservoir storage, instream flows, and water temperatures during egg incubation) in the Feather River, Trinity River, San Joaquin River, or Clear Creek for spring-run Chinook salmon based on results from the Reclamation egg mortality model, SALMOD, CALSIM outputs, and other tools. Most spring-run Chinook salmon spawn in tributaries such as the Feather River and Mill, Deer, Butte, and Clear Creeks, in which spring-run egg mortality would not be affected by BDCP operations.

In the Sacramento River, there is a 5–10% increase in egg mortality of spring-run under BDCP operations relative to existing biological conditions in wet, above-normal, and below-normal water years. This increase was a result of increase water temperatures during fall months, particularly September. Refinements in reservoir operations and coldwater pool management, including real-time management, which CALSIM cannot model, may reduce this effect, but this has not been evaluated using the hydrologic and water temperature simulation models. The potential impact of estimated increases in egg mortality on spring-run Chinook salmon to the entire population is reduced, in part, by the fact that only a small proportion (approximately 10%) of the entire population spawns in the Sacramento River. Further, results of the SacEFT and SALMOD models, which account for flow, temperature, and other variables in the upper Sacramento River, predict that spawning habitat conditions will not be different (SALMOD) or will be improved (SacEFT) under the proposed project compared to existing biological conditions, which is in contrast to egg mortality model results.

Fall-run Chinook salmon. No major adverse effects were detected on upstream spawning or egg incubation habitat conditions (e.g., reservoir storage, instream flows, and water temperatures during egg incubation) for fall-run Chinook salmon in the Sacramento River based on results of model analyses using Reclamation egg mortality model, SacEFT, SALMOD, and other tools. Small positive and negative changes were detected in the Sacramento River, such as reduced summer and fall flows relative to existing conditions. No substantive changes in reservoir storage or river flows affecting fall-run Chinook salmon habitat conditions were detected in the Feather, American, San Joaquin, Stanislaus, or Trinity Rivers or Clear Creek. BDCP operations have no effect on flows or water temperatures in other tributaries, including the Mokelumne, Cosumnes, Merced, and Tuolumne Rivers, or habitats in areas such as Mill, Deer, Butte, and Battle Creeks.

Late fall-run Chinook salmon. No major adverse effects were detected on late fall–run Chinook spawning and egg incubation habitat conditions in the Sacramento River based on CALSIM, SacEFT, SALMOD, and other modeling tools. Although most changes in spawning habitat were attributable to climate change, the SacEFT model indicated that BDCP operations would result in a small incremental reduction (5%) in the number of years with “good” spawning habitat conditions for late fall–run Chinook salmon.

White and green sturgeon. Spawning white sturgeon and their eggs would experience similar flow and water temperature conditions under BDCP operations relative to existing biological conditions. There are small beneficial and adverse effects to spawning and egg incubation habitat conditions, but no major or consistent adverse effects were detected in the Sacramento, Feather, or Stanislaus Rivers. The greatest changes in upstream habitat conditions resulted from natural variation in interannual hydrology (e.g., between wet and dry years) and future climate change. These major habitat effects were largely independent of differences between existing conditions and BDCP operations. Likewise, no major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., instream flows and water temperatures during egg incubation) in the Sacramento River for green sturgeon based on results from the Reclamation egg mortality model, SacEFT, CALSIM outputs, and other tools. In the Feather River however, there is a reduction in flows during July and August of 29% on average. However, this effect does not translate into a consistent adverse effect on green sturgeon based on water temperature exposure. There were no meaningful differences between existing biological conditions and BDCP operations in exceedance of water temperature tolerances of 63°F and 68°F. The only effect is an increase of exposure to the upper threshold of green sturgeon tolerance of 73°F in up to 8% more months under BDCP operations compared to existing biological conditions.

Pacific and river lamprey. No major or consistent adverse effects were detected on upstream spawning and egg incubation habitat conditions (e.g., reservoir storage, instream flows, and water temperatures during egg incubation) for Pacific lamprey and river lamprey based on results from the Reclamation egg mortality model, CALSIM, and other tools.

C.4.2.2 Holding Flows

Holding flows were evaluated for spring- and winter-run Chinook adults. As described below, no adverse effects of the BDCP are expected.

The BDCP would have no effects on spring- or winter-run Chinook salmon adult holding flows.

No major or consistent adverse effects were detected on upstream adult holding habitat conditions (e.g., instream flows) in the Sacramento River for spring- and winter-run Chinook salmon, or in the Feather and Trinity Rivers or Clear Creek for spring-run Chinook salmon based on results from CALSIM. The greatest changes in upstream habitat conditions resulted from natural variation in interannual hydrology (e.g., between wet and dry years) and future climate change. Increased adverse conditions reflect natural seasonal and interannual variation in river flows, coldwater storage, and temperature effects on holding adults that were largely independent of BDCP operations.

C.4.2.3 Upstream Rearing Habitat

Upstream rearing habitat for covered species would not change substantially, although some increase in Feather River temperature may adversely affect green sturgeon and river lamprey, and a decrease in late fall–run Chinook rearing habitat may also occur. For spring-run Chinook, fall-run Chinook, green sturgeon, white sturgeon, Pacific lamprey, and river lamprey, the greatest changes in upstream habitat conditions resulted from natural variation in interannual hydrology (e.g., between wet and dry years) and future climate change. Increased adverse conditions reflects natural seasonal and interannual variation in river flows, coldwater storage, and temperature effects on rearing habitat that were largely independent of BDCP operations.

Upstream rearing habitat for covered species would not change substantially; however, some adverse effects on on late fall–run Sacramento River rearing habitat and on green sturgeon and river lamprey rearing habitat as a result of increases in Feather River temperature, and some benefits to winter-run rearing habitat, are expected.

Steelhead. No major adverse effects were detected on steelhead fry/juvenile rearing habitat conditions based on CALSIM, SacEFT, and water temperature modeling results. The predicted magnitude and frequency of instream flows, reservoir storage, and water temperatures potentially affecting the quantity and quality of rearing habitat under proposed project and future baseline conditions were comparable. Most of the differences and associated effects on steelhead rearing habitat observed among the modeled scenarios were attributable to near- and long-term climate change effects. Based on the results, BDCP operations would likely have small annual effects on flows and water temperatures affecting steelhead rearing habitat, but would not affect long-term habitat conditions relative to future baseline conditions. In the Sacramento River between the Red Bluff Diversion Dam and Keswick, the SacEFT model indicated that BDCP operations would result in a small incremental increase (5%) in the number of years with "good" rearing habitat conditions for steelhead.

Winter-run Chinook salmon. The SacEFT model predicted that winter-run Chinook fry/juvenile rearing habitat in the Sacramento River would be classified as "good" in 23–26% more years under BDCP operations relative to existing conditions.

Spring-run Chinook salmon. No major or consistent adverse effects were detected on upstream fry/juvenile rearing habitat conditions (e.g., instream flows, water temperature, and stranding) in the Feather River, Trinity River, San Joaquin River, or Clear Creek for spring-run Chinook salmon based on results from CALSIM and the Reclamation water temperature model.

Fall-run Chinook salmon. No major or consistent adverse effects were detected on upstream fry/juvenile rearing habitat conditions (e.g., instream flows, water temperature, and stranding) in upstream waterways for fall-run Chinook salmon based on results from CALSIM and the Reclamation water temperature model.

Late fall–run Chinook salmon. No adverse effects were detected on late fall-run Chinook fry/juvenile rearing habitat conditions in the Sacramento River based on CALSIM, SALMOD, and water temperature modeling. The predicted magnitude and frequency of instream flows, reservoir storage, and water temperatures potentially affecting the quantity and quality of rearing habitat in the Sacramento River under proposed project and future baseline conditions were comparable. Most of the differences and associated effects on late fall–run Chinook salmon rearing habitat observed among the modeled scenarios were attributable to near- and long-term climate change effects. Despite these results, the SacEFT model indicated that BDCP operations would result in an incremental reduction of 14–28% in the number of years with "good" rearing habitat conditions for late fall–run Chinook salmon. However, based on the weight of evidence (SALMOD results, flow and temperature exceedance analyses), there should be no detectable change in rearing habitat conditions for late fall-run Chinook in the upper Sacramento River.

Green and white sturgeon. No major or consistent adverse effects were detected on upstream larvae/juvenile rearing habitat conditions (e.g., instream flows, water temperature, and stranding) in the Sacramento River or upstream waterways for green or white sturgeon based on results from CALSIM and the Reclamation water temperature model. Additionally, larval and juvenile white sturgeon would experience similar or slightly improved flow and water temperature conditions. Green sturgeon larvae will experience reduced flows in the Feather River from July through September, when flows are reduced by 42% on average in wet, above-normal, below-normal, and dry water years. However, reduced flows are not expected to translate into water temperature effects in a major or consistent way, except during the LLT implementation period, during which exposure to the upper 73°F water temperature threshold will occur 5–14% more often under BDCP operations than under existing biological conditions.

Pacific and river lamprey. No major or consistent adverse effects were detected on upstream ammocoete rearing habitat conditions (e.g., instream flows, water temperature, and stranding) in upstream waterways for Pacific lamprey or in the Sacramento, Trinity, American, and Stanislaus Rivers for river lamprey based on results from CALSIM and the Reclamation water temperature model. In the Feather River below Thermalito Afterbay, there is a small to moderate increase in exposure to elevated water temperatures, although this effect is not observed farther upstream at the Fish Barrier Dam. This increase in exposure to elevated water temperatures is expected to result in a small to moderate increase in mortality of ammocoetes in the region below the Thermalito Bypass.

C.4.2.4 Passage, Migration, and Movement

Passage, migration, and movement were evaluated for upstream and Delta areas for all species. Overall, the results indicate that there will be some improved and some reduced passage as a result of the BDCP.

Overall, upstream flows during migration and transport periods for anadromous fish are not substantially changed under the BDCP, with some exceptions.

The great majority of modeled river flow estimates upstream of the Plan Area suggested that, once effects associated with climate change were factored out, average differences in flow between PP and EBC during covered fish species migration and transport periods would be minor (Table C-7). The general pattern was for little change, with minor increases or decreases depending on water year type. There were essentially no changes in migration flows in Clear Creek, the Stanislaus River, and the San Joaquin River at Vernalis. Analyses were based on the assumption that migration and transport are enhanced with increased flows, although there were few specific thresholds or ranges that could be applied. Summaries of the main patterns are provided below.

Steelhead. The Feather River was the only location where migration flows during periods of steelhead occurrence exhibited a number of differences between preliminary proposal and existing conditions: migration flows for juveniles and kelts were somewhat (generally 10% or more) greater under the preliminary proposal in most water-year types, but for adults, preliminary proposal flows were only greater (10–20% more) in dry and critical years.

Winter-run Chinook salmon. The analysis suggested little difference between existing conditions and preliminary proposal average flows during the juvenile downstream migration period in the upper Sacramento River (River Mile 194 to Keswick).

Spring-run Chinook salmon. As with steelhead, the Feather River was the only location with appreciable differences in migration flows between preliminary proposal and existing conditions, with the former averaging 5–30% greater than the latter in most water-year types.

Fall-run/late fall–run Chinook salmon. Migration flows for fall-run Chinook salmon were generally little different between preliminary proposal and existing conditions at most locations, except the Sacramento River (RM 194 to Keswick), American River, and Feather River. In the upper Sacramento River, adult migration flows were around 10–20% less under the preliminary proposal in wet and above-normal water years, and either similar or up to 20% greater under the preliminary proposal in the remaining water-year types. In the American River, appreciably less average adult migration flow (7–26%) occurred under preliminary proposal conditions than existing conditions in wet and above-normal years, whereas in critical years preliminary proposal flows were 13–39% greater. Juvenile migration flows in the Feather River averaged around 10–20% greater than existing biological conditions for above-normal, below-normal, and dry years and were similar in other years. Adult migration flows were 12–32% less on average under the preliminary proposal in wet, above-normal, and below-normal years, in contrast to a similar percentage greater under the preliminary proposal in critical years. For late fall–run Chinook salmon adults, there was little difference in migration flows between the preliminary proposal and existing conditions in the Sacramento River (River Mile 194 to Keswick).

White sturgeon. Analyses for white sturgeon focused on the Sacramento River (north Delta to River Mile 143 subregion—i.e., Wilkins Slough and Verona CALSIM nodes). For juveniles, average migration flows at Verona were more than 5% lower under the preliminary proposal scenarios in all water-year types, ranging from around 6–11% in critical years to 20% in wet years. Larval transport flows were represented by the average number of months per year that exceeded thresholds of 17,700 cfs (Wilkins Slough) and 31,000 cfs (Verona) and were variable in terms of estimated effects. The results ranged from little change or somewhat more frequent exceedances of flow thresholds (16% greater in above-normal years) under the preliminary proposal relative to existing conditions at Wilkins Slough, to reduced flow threshold exceedances at Verona of 9–50%. (The latter value occurred in dry years, when the average number of months exceeding the threshold was low regardless of scenario.)

Green sturgeon. Flows for green sturgeon migration were analyzed in the upper Sacramento River and Feather River and demonstrated contrasting changes for different life stages. Preliminary proposal flows that were lower than flows under the existing conditions were evident for larvae and juveniles in both systems and occurred primarily in wet, above-normal, and below-normal years, with the preliminary proposal flows in the Feather River falling in the 25–50% reduction category on average and those in the Sacramento River falling in the 5–25% reduction category. In contrast, adult migration flows were either similar or else, in the case of the Feather River, appreciably increased.

Pacfic lamprey. Average flows during Pacific lamprey migration periods were quite similar under the preliminary proposal and existing conditions (or slightly greater, up to 10%, under the preliminary proposal) on the Sacramento River (River Mile 194 to Keswick), Feather River, American River, Stanislaus River, and San Joaquin River at Vernalis.

River lamprey. Average flows during river lamprey migration periods generally were quite similar under the preliminary proposal and existing conditions for macropthalmia, with differences occurring for adults that typically indicated lower flows under the preliminary proposal than existing conditions. For adults, the difference was less than 5% for the Stanislaus River and San Joaquin River at Vernalis, whereas flows were 6–13% lower under the preliminary proposal for the Sacramento River (River Mile 194 to Keswick), Feather River, and American River.

Attraction flows and olfactory cues in the west Delta for upstream anadromous migrating fish will be altered because of shifts in exports from the south Delta to the north Delta under the BDCP.

Sacramento River flows downstream of the north Delta intakes will be reduced under BDCP operations relative to existing conditions, while reduced exports in the south Delta generally will increase the proportion of water in the west Delta originating from the San Joaquin River. The change in olfactory cues (percentage of Sacramento River or San Joaquin River water at Collinsville predicted using DSM2 modeling within the fingerprint analysis) differed by species (Table C-7). Under the preliminary proposal, the average percentage of Sacramento River–origin water was always lower than for the existing conditions, ranging from 2–4% less in steelhead to 8–10% less in fall-run Chinook salmon. Under the preliminary proposal, the percentage of San Joaquin water was generally considerably greater than under existing conditions, at least in relative terms; however, the actual percentages involved were low (single digits) because a very low percentage of San Joaquin River water contributes to the water in the west Delta in any scenario.

Adult attraction/migration flows at Rio Vista under the preliminary proposal were lower than flows under existing conditions for most water-year types. The relative difference between scenarios ranged from 5–9% in all except critical water years (little changed) for winter-run and late fall–run Chinook salmon to more than 20% in some water-year types for steelhead, spring-run Chinook salmon, and fall-run Chinook salmon; the latter species had up to around 50–60% lower average flows under the preliminary proposal in wet and above-normal years. In dry and critical years, differences in migration flows between preliminary proposal and existing conditions were often less than 5%, and in some cases preliminary proposal flows were greater (e.g., fall-run Chinook salmon in the LLT).

The BDCP improvements in fish passage facilities at the Fremont Weir and within the Yolo Bypass (CM 2) will reduce delay and stranding of upstream migrating adult anadromous covered fish species.

The suite of actions proposed to improve adult fish passage as part of CM 2 (Yolo Bypass Fisheries Enhancements) is expected to benefit covered fish species by reducing stranding and delay in the Yolo Bypass. Limited stranding and rescue data indicate that appreciable percentages (10% or more) of the green sturgeon spawning population in particular may be currently negatively affected by the passage impediment caused by the Fremont Weir. The efficacy of the passage improvements at the Fremont Weir and other locations within the Yolo Bypass (e.g., Lisbon Weir) will be monitored, and adjustments will be made through adaptive management, but overall this CM promises to have a major positive effect on upstream migrating anadromous covered fish species, in particular sturgeons and salmonids.

Chinook salmon smolt survival during outmigration through the Delta includes tradeoffs between positive and negative flow changes in the Yolo Bypass and Sacramento River, with uncertainty to be informed by monitoring and adaptive management.

The results of the DPM showed that through-Delta survival of Chinook salmon smolts was generally similar or slightly lower under the preliminary proposal than under existing biological conditions. The reductions in survival ranged from considerably less than 1% of the smolts entering the Delta (San Joaquin–origin fall-run Chinook) to 1–3% of smolts for fall-, spring-, and winter-run Chinook from the Sacramento River. The observed patterns represented tradeoffs between positive and negative aspects of the preliminary proposal relative to the existing biological conditions, as assumed in the model. Positive aspects of the preliminary proposal include the increased diversion of fish into the Yolo Bypass for smolts migrating down the Sacramento River that encounter the new notch at the Fremont Weir. The Yolo Bypass migration route is assumed to have survival equal to the maximum survival in the nearby Sacramento River, as well as offering the advantage of avoidance of diversion through Georgiana Slough or the DCC into the low-survival interior Delta. The benefits of increased entry into the Yolo Bypass were greatest for winter-run Chinook, followed by spring-run and finally fall-run, for which there was little benefit because their assumed timing is during a period when Yolo Bypass inundation is generally too low to promote appreciable diversion. The relatively good survival assumed through the Yolo Bypass is based on studies conducted on fish smaller than smolts, and the assumption will require refinement based on monitoring studies of acoustically tagged smolts to be conducted in the future. Reductions in south Delta exports also improve survival of smolts, although as noted in the entrainment appendix (Appendix B), there are situations in drier water years where exports from the south Delta are increased because of bypass requirements at the north Delta intakes. Such situations generally arise during the fall-run migration period and explain the lower survival through the interior Delta of this race.

Negative aspects of the preliminary proposal include an assumed increase in predation of Sacramento River–origin smolts in the vicinity of the north Delta intake structures because of predators holding station in the area; the current modeling assumed around 1% of each run would be lost, but again this number is uncertain and will be refined through targeted studies. The potential benefits of habitat restoration within the Delta are also not captured by the DPM results, which focus on flow-related survival and migration routes through the Delta.

Reduction in Stockton Deep Water Ship Channel DO levels (CM 14) will improve upstream migration conditions for fall-run Chinook salmon, steelhead, and other species in the San Joaquin River basin.

Preliminary results from the oxygen diffusion system that forms the basis for CM 14 suggest that it will raise DO levels to meet total maximum daily load objectives (at least 6 milligrams per liter [mg/l] of DO from September 1 to November 30, and at least 5 mg/l at all times). This should eliminate any passage impediments caused by low DO in this area for upstream migrating adult fall-run Chinook salmon and steelhead in the San Joaquin River basin. Improvement of DO in the vicinity of the ship channel will also benefit any other covered fish species using that area of the Delta.

Modification of the Suisun Marsh Salinity Control Gate operation will improve passage for adult anadromous fish.

As operations of the Suisun Marsh Salinity Control Gate become less frequent with restoration of areas within the Suisun Marsh ROA, upstream passage for adult anadromous fish such as Chinook salmon, steelhead, sturgeons, and lampreys will have less potential for delay and subsequent effects on reproduction in natal tributaries.

Nonphysical fish barriers (CM 16) have the potential to inhibit juvenile fish from entering the interior Delta, but further research is necessary to evaluate effectiveness; unintended passage impedance for adults also requires research.

Juvenile Chinook salmon and steelhead, and juvenile and adult Delta smelt, longfin smelt, and Sacramento splittail are most likely to benefit from nonphysical barriers at important channel divergences such as Sacramento River–Georgiana Slough and San Joaquin River–Old River because these species have hearing abilities that are likely to respond to the main barrier stimulus (i.e., the acoustic signal). As such, these barriers could be an effective tool for precluding these species from entering the interior Delta, where mortality may be higher than in the main channels of the Sacramento and San Joaquin Rivers. There is little potential to inhibit interior Delta entry of white and green sturgeon or Pacific and river lamprey because these species have little sensitivity to the acoustic deterrence of the nonphysical barriers; further, in the case of deep channels, the barriers are not constructed to include the channel bottom area where benthic-oriented species like sturgeon would be migrating. The effectiveness of nonphysical barriers will depend on the water-velocity characteristics in the vicinity of the barrier and on the extent to which predatory fish congregate along the barrier.

However, nonphysical barriers could be encountered by upstream migrating adult anadromous fishes (e.g., winter- and spring-run Chinook salmon, steelhead, Sacramento splittail, sturgeons, and lampreys). The potential for impedance or delay would be low for fish with poor hearing ability (sturgeons and lampreys), whereas the potential for impedance of the other species would increase as water depth decreases and a greater portion of the water column is occupied by the barrier. Ongoing testing at Georgiana Slough and the head of the Old River will provide more insight into the potential effectiveness of this CM under various flow and geomorphic conditions, as will monitoring, research, and adaptive management of the CM.

Reduced Sacramento River flows may reduce longfin smelt and Delta smelt larval transport, with the potential to reduce survival for longfin smelt.

Decreased transport flows in the lower Sacramento River have been identified as one mechanism that could adversely affect the growth and survival of larval delta and longfin smelt. Compared to existing biological conditions, the preliminary proposal reduces Delta outflows during the winter-spring Delta smelt and longfin smelt larval period, potentially reducing downstream longfin larval transport and subsequent survival. Projected reductions assume a direct relationship between outflow (expressed as X2) and longfin smelt abundance. However, the correlation is not understood, and it may not reflect larval transport but may instead be reflective of some other relationship.The longfin smelt analysis estimated that once climate change–related flow effects had been factored out, changes in outflow during the larval period have the potential to reduce abundance of older life stages represented in Bay-Delta trawl surveys by 8–24% in the ELT and 1–18% in the LLT on average.

For Delta smelt, larval transport under the preliminary proposal was represented by the numbers of particles reaching Martinez and ranged from little change from existing conditions up to a 20% decrease, after accounting for flow-related climate change effects. In contrast to longfin smelt, relationships estimating subsequent abundance of older life stages from changes in transport flows are not present, so the estimated changes solely reflect changed potential in larval transport.

C.4.2.5 Delta Area Effects

Changes in Sacramento River flow may result in an overall decrease in channel margin bench habitat, but restoration will offset this effect.

Results of an analysis of the effects of changes in Sacramento River flow and water surface elevation on channel margin bench habitat showed that, in general, the frequency of channel bench inundation would be reduced (greater than 5%, but variable among north Delta sites). A reduction in the frequency of channel bench habitat inundation in the north Delta in response to reductions in river flow and water surface elevation would be mitigated through expansion of aquatic habitat in the north Delta (e.g., Cache Slough restoration) and construction of additional channel margin bench habitat along the Sacramento River, as described for CM 4.

The general reduction in OMR reverse flows and the corresponding increase in net positive downstream flows through the south Delta channels are expected to improve migration cues, improve migration rates and pathways, and contribute to improved larval and juvenile survival and reduced adult straying, although reverse OMR flows will be greater in certain water-year types.

As a result of the preliminary proposal operations, the frequency and magnitude of OMR reverse flows are expected to be reduced significantly during the late winter and spring period for wet, above-normal, and critical years, which coincides with the seasonal period of migration of many of the juvenile fish such as Chinook salmon, steelhead, larval and juvenile Delta and longfin smelt, and juvenile splittail through the interior Delta channels. The predicted improvements in south Delta flow conditions (significantly reduced OMR reverse flows, improved net positive downstream flows, improved olfactory cues, and attraction flows for the San Joaquin River and its tributaries) are significant benefits of the preliminary proposal operations on flow conditions affecting habitat, migration, and survival of fish inhabiting the Delta. Improved hydrologic conditions in the south Delta in response to proposed project operations are expected to contribute to improvement in the

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flow cues followed by juvenile and adult fish passing upstream and downstream through the Delta and thereby improve migration and survival and reduce straying. Reduction in OMR reverse flows is also expected to reduce the movement of planktonic larval and juvenile fish (e.g., Delta and longfin smelt, Chinook salmon) from the Sacramento River through the interior Delta to the south Delta and thereby improve their survival and abundance. However, as noted in Appendix B (Entrainment), OMR reverse flows may be increased in the late winter/spring in drier water-year types because of export restrictions at the north Delta intakes, which would negatively affect species present there at the time, such as juvenile spring-run Chinook salmon and larval-juvenile Delta smelt.

In dry and below-normal water years, the reverse OMR flows are increased compared to existing biological conditions, which may translate to adverse effects on Chinook and splittail juveniles, and Delta smelt and longfin smelt larva and juveniles. However, the reverse OMR flows under the BDCP for all water years are still within the requirements of the NMFS and USFWS BOs for CVP and SWP operations, and the biological response of these species to relatively small OMR reverse flow changes may not result in adverse changes in species survival.

Increased Yolo Bypass inundation will contribute to substantial biological benefits to splittail spawning and rearing; winter- and fall-run juvenile rearing; and steelhead, late fall–run, green sturgeon, and Pacific lamprey adult migration.

Based on results of hydrologic models, modification to the Fremont Weir to increase inundation of the bypass floodplain during the winter and spring months (CM 2) would contribute to substantial biological benefits to splittail spawning success, and rearing and migration by other juvenile and adult fish. The benefits of increased inundation were found to be greatest in wet, above-normal, and below-normal water years, when seasonal flows in the Sacramento River are greatest with little or no change in inundation in dry and critically dry years when river flows are low. The anticipated benefits would be greatest for those fish that rear within floodplain habitats as juveniles during downstream migration, including juvenile winter- and fall-run Chinook salmon. Other fish such as steelhead, late fall-run Chinook salmon, green and white sturgeon, and Pacific lamprey would be expected to benefit from using the flooded bypass as a migratory corridor, but would not be expected to rear extensively within the flooded area. Splittail, which spawn on seasonally inundated floodplain habitat, would be expected to benefit from access to spawning and juvenile rearing floodplain habitat. Fish species such as splittail and juvenile Chinook salmon that historically used seasonally inundated floodplain habitat for spawning or juvenile rearing have adapted behavior to respond to flow recessions and draining of floodplain habitat. As a result, the risk of stranding juvenile fish within the Yolo Bypass has not been identified as a major potential source of mortality.

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